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Report of the Select Committee of the Ontario Legislature on

LAKE LEVELS

OF THE GREAT LAKES

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REPORT

of the

Select Committee

of the

Ontario Legislature

on

LAKE LEVELS

OF THE GREAT LAKES

ONTARIO

TORONTO
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1953

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TO THE HONOURABLE THE LEGISLATIVE ASSEMBLY
OF THE
PROVINCE OF ONTARIO

Honourable Members:

On March 28th, 1952, during the First Session of the Twenty-fourth Legislature, the following resolution was passed:

"That a Select Committee of this House be appointed to study the matter of lake levels in the Great Lakes or waters affected thereby, and more particularly to inquire into:

(1) the causes of the variations of water levels,

(2) the effect of such water levels on shore erosion, silting of shore margins and conservation generally,

(3) the present methods of control of water levels,

(4) under what jurisdiction such controls operate,

(5) to study and report on the laws of Canada or any jurisdiction fronting on such lakes and which affect such levels, erosions, silting and conservation,

(6) the means presently adopted in the various jurisdictions to cope with the problems mentioned in paragraph (5),

"And to report to the House at its next Session on what steps can be taken to protect the shores of such lakes and waters and by what authority.

"And that the Select Committee have authority to sit during the interval between Sessions and have full power and authority to appoint or employ counsel and secretary and such other personnel as may be deemed advisable and to call for persons, papers and things and to examine witnesses under oath, and the Assembly doth command and compel attendances before the said Select Committee of such persons and the production of such papers and things as the Committee may deem necessary for such proceedings and deliberations, for which purpose the Honourable the Speaker may issue his warrant or warrants."

"And the said Committee to consist of eleven members to be composed as follows: Messrs. Villeneuve (Chairman), Griesinger, Thomas (Elgin), Child, Murdoch, Beckett, Macaulay, Myers, Oliver, Houck, Thomas (Ontario)."

This Committee, having completed its work, respectfully presents the report which follows:

SIGNED:

O. F. Villeneuve

W. Griesinger

F. S. Thomas

A. Child

W. Murdoch

H. Beckett

Macaulay

Wm. Myers

F. R. Oliver.

W. L. Houck

T. D. Thomas

Dated at Toronto, March 1, 1953.

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TERMS OF REFERENCE

During the winter and early spring of 1952 the levels of the Great Lakes rose to such an extent that serious damage was done to the shoreline and in many cases to buildings and other structures situated thereon. In addition some areas bordering on the Great Lakes were flooded, with the result that hundreds of residents were driven from their homes and in many cases these were destroyed or made uninhabitable.

Following this widespread damage, many representations were made to the Ontario Government requesting protection against a similar occurrence in the future and to assist in repairing the damage which had been done.

Accordingly, the Government of Ontario, realizing that high lake levels may repeat themselves in the future, considered that it was both expedient and necessary to review its powers to deal with this problem. Therefore, on March 28, 1952, the Legislature of Ontario appointed a Select Committee to study these matters and instructed it to report back at the next regular sitting of the Legislature.

The terms of reference for this Committee set out six specific items for inquiry and consideration. These, with the sections in which they are dealt with in this report, are as follows:

(1) "The causes of the variations of water levels"

5 - Factors Affecting Lake Levels, sections 4, 5, 6

(2) "The effect of such water levels on shore erosion, silting and conservation generally"

4 - Factors Affecting Shore Erosion, section 4

(3) "The present method of control of water levels"

5 - Regulation of the Lake Levels in the Great Lakes, section 7

(4) "Under what jurisdiction such controls operate"

5 - Regulation of the Lake Levels in the Great Lakes, section 7

(5) "To study and report on the laws of Canada or any jurisdiction fronting such lakes and which affect such levels, erosion, silting and conservation"

6 - Jurisdictional Aspects of Shore Protection

(6) "The means presently adopted in the various jurisdictions to cope with the problems mentioned in paragraph 5"

7 - Basic Principles of Protective Measures

8 - Types of Shore Protection

9 - Miscellaneous Protective Methods

10- Emergency Protective Methods

11- Inundated Areas

12- The Long Branch Survey

The Committee has been impressed with the lack of fundamental information that is available on the processes of shore erosion and the application of effective means for its control. Throughout its study the problems of shore erosion and inundation have been considered in the light of all the other uses of water of the Great Lakes, some of which have national and even international significance.

SUMMARY OF RECOMMENDATIONS

ACKNOWLEDGMENTS

In conducting an inquiry of this nature the Committee set out to see for itself the areas which were most seriously affected by shore erosion and inundation on the Great Lakes, to view the extent of damage and to interview the residents of these affected areas, their municipal representatives together with numerous delegations. The Committee was impressed with the sincerity of so many citizens who gave of their time to assist in this study.

The technical nature of the terms of reference required considerable dependence upon the departments of governments which have studied aspects of this problem. The Committee keenly appreciates the co-operation of public servants in the Ontario Departments of the Attorney-General, Health, Highways, Lands and Forests, Mines, Planning and Development and Public Works.

Scientific and technical data given by the Dominion Departments of Mines and Technical Surveys, Resources and Development and Transport were of inestimable value in the preparation of this report.

It is a pleasure to record the courtesies extended by the Corps of Engineers, United States Army and by the Shore Erosion Division of the Ohio Department of Natural Resources, who discussed administrative and technical aspects of this work and who showed the Committee types of protective measures within their jurisdictions. The Committee also acknowledges the technical and engineering data provided by the United States Beach Erosion Board and by many of the Atlantic coast states.

The contribution made by Dr. G. B. Langford of the University of Toronto, as a consultant is gratefully acknowledged. For able assistance and advice the Committee wishes to thank Mr. A. H. Richardson, Chief Conservation Engineer, and Mr. J. W. Murray, Hydraulic Engineer, both of the Conservation Branch of the Department of Planning and Development. The services of Mr. H. F. Crown of the same Department, who served as secretary to the Committee are greatly appreciated.

PART ONE

DESCRIPTIVE AND TECHNICAL DATA

PART ONE

1

PHYSICAL CHARACTERISTICS OF THE GREAT LAKES

The Great Lakes system consisting of Lakes Superior, Michigan, Huron, St. Clair, Erie and Ontario and connecting rivers is the largest inland body of fresh water in the world. The water-surface of these lakes and their connecting rivers is 95,160 square miles of which 34,210 are in Ontario and 60,950 are in the United States. The watershed of the Great Lakes above Prescott on the St. Lawrence River drains an area of 298,090 square miles of which 121,840 are in Ontario and 176,250 are in the United States. The distance travelled by shipping from Duluth on the western end of Lake Superior to Kingston on the eastern end of Lake Ontario is 1,220 miles; from Kingston to the Gulf of St. Lawrence is a further 700 miles. Thus the Great Lakes and its connecting rivers reach almost 2,000 miles into the continent. The total length of the Ontario mainland shoreline is approximately 3,000 miles.

At Prescott where the system has received only the run-off from the watershed of the Great Lakes, the St. Lawrence River has an average rate of discharge for the period 1860 - 1951 of 237,000 cubic feet per second. The drop in elevation from Lake Superior to Lake Ontario is 356 feet; from Lake Ontario to Lake St. Francis in the St. Lawrence River, five miles east of the City of Cornwall, the drop is 92 feet, or a total of 448 feet.

The mean annual precipitation on the entire Great Lakes and its drainage basin for the period 1890 - 1951 is 31.18 inches.

Lake Superior

Lake Superior is the largest and deepest of the Great Lakes. The length of the vessel track from Duluth on its western tip to the mouth of the St. Marys River is 383 miles. The water-surface area is 31,820 square miles of which 11,110 are in Ontario and 20,710 are in the United States. Lake Superior contains about one third of the total reservoir capacity of the system.

The deepest water in the lake is south of Michipicoten Island where it reaches a depth of 1,302 feet. The bottom of the lake at this point is about 700 feet below sea level. Depths of 300 feet or more are reached within twenty miles of the northern and eastern sections of the shore whereas on the southern shore these depths are generally not obtained until fifty miles off the shore.

The average level of the lake for the period 1860 - 1952 has been 602.29 feet above sea level. The highest monthly mean level is thought to have occurred in 1838 when it is estimated that it reached a monthly mean level of 605.32 feet. Since 1860 the highest water occurred on September, 1869, with a monthly mean level of 604.08 feet. The lowest monthly mean level since 1860 occurred in April, 1926, when the monthly mean was 599.90 feet.

The Ontario mainland shoreline on Lake Superior is approximately 760 miles. The shore is predominantly rocky with sand and gravel beaches in the bays and at the mouths of the rivers.

The drainage basin of the lake is 80,900 square miles of which 43,330 are in Ontario and 37,570 are in the United States.

The mean annual precipitation on the Lake Superior drainage basin for the period 1890 - 1951 is 28.82 inches.

St. Marys River

The St. Marys River is the outlet of Lake Superior and flows in a southeasterly direction through several channels for a distance of over 70 miles to Lake Huron. The river descends 22½ feet in its length, most of the drop occurring at the St. Marys Falls. The shores of the river are composed mostly of low sand and clay banks lying over granitic rocks. In addition to dredged channels throughout most of the length of the river, certain other navigation facilities have been provided. These consist primarily of the four navigation locks at the St. Marys Falls in the two American canals and one navigation lock in the Canadian canal.

The natural control of the outflow from Lake Superior was the rock ledge at the head of the St. Marys River. This natural control has been replaced by the locks, compensating works, and power houses, so that the outflow is now completely controlled and the level of Lake Superior is regulated. The average discharge from Lake Superior through the St. Marys River since the year 1900 has been 73,200 cubic feet per second.

Lake Huron

Lake Huron is the second largest of the Great Lakes. The water-surface area is 23,010 square miles of which 13,900 are in Ontario and 9,110 are in the United States. The length of the vessel track from the mouth of the St. Marys River to Point Edward at the head of the St. Clair River is 253 miles. The lake is 101 miles wide at its greatest breadth. The maximum recorded depth of the lake is 750 feet where the bottom is 169 feet below sea level. This depth occurs about 25 miles off the west coast of the Bruce Peninsula.

Lake Huron is connected to Lake Michigan by the broad, deep straits of Mackinac. As there is no perceptible fall in these straits, Lakes Huron and Michigan are considered as one lake from the standpoint of hydraulics.

From Grand Bend to Port Franks on Lake Huron the shore is low lying and is noted for its broad sandy beaches

The eighty mile stretch of shoreline from Point Aux Pins to Long Point on Lake Erie is composed of clay and sand bluffs which rise to heights exceeding 100 feet in Malahide Township.

The average level of Lake Huron for the period 1860 - 1952 has been 580.57 feet above sea level. The highest monthly mean level is thought to have occurred in 1838 when it is estimated that it reached a monthly mean level of 584.69 feet. Since 1860 the highest monthly mean level was 583.66 feet occurring in July, 1876. The lowest monthly mean level since 1860 was 577.42 feet in February, 1934.

The length of Ontario's mainland shoreline on Lake Huron is 1,320 miles. From the mouth of the St. Marys River to within a few miles north of Wasaga Beach on Nottawasaga Bay, the shoreline is very rocky and highly resistant to erosion. At the end of the Nottawasaga Bay the shore is low lying and sandy and is backed by marshes. At Meaford the clay and sand bluff shoreline appears and gives way to limestone bluffs which continue for most of the coast of the Bruce Peninsula. On the west coast of the Bruce Peninsula the bluffs gradually become lower towards the south and give way to a section of low lying sand beaches from Oliphant to within a few miles north of Southampton. From Southampton to Goderich the shoreline is characterized by clay and sand bluffs which attain a height of 40 feet at some points. South of Goderich to the head of the St. Clair River these bluffs gradually diminish to sand plains, backed by extensive marshes which are subject to inundation during periods of high lake levels.

The drainage basin of Lake Huron is 72,420 square miles of which 47,570 are in Ontario and 24,850 are in the United States.

The mean annual precipitation on the Lake Huron drainage basin from 1890 - 1951 is 31.52 inches.

St. Clair River, Lake St. Clair and Detroit River

The outflow from Lake Huron is conveyed through the St. Clair River, Lake St. Clair and the Detroit River for a distance of 85 miles to Lake Erie, with a fall of only

eight feet in this reach. In general, the shoreline of this entire section is flat and is backed by low lying plains. The composition of the banks and shoreline varies from gravelly sand in the upper part of the St. Clair River to clay on Lake St. Clair. The total length of the Ontario mainland shoreline on the St. Clair River, Lake St. Clair and Detroit River is approximately 120 miles. There is no definite natural control section such as a rock ledge on the St. Clair or Detroit Rivers which determines the discharge from Lake Huron. The entire system is the control and the discharge depends on the difference between the elevations of Lakes Huron and Erie.

Lake St. Clair is very shallow, having a depth no greater than eighteen feet excepting in the dredged navigation channels. Dredging is required to maintain such channels throughout most of the length of this system, especially at the head of the St. Clair River where it leaves Lake Huron; in the lower St. Clair River, and across Lake St. Clair to the head of the Detroit River. In the lower reaches of the Detroit River, sections of the navigation channel were cut through rock. Other navigation works are the dykes on the east side of the channel where the St. Clair River enters Lake St. Clair. In the lower Detroit River where river capacities were greatly increased by the deepening of the channel, compensating dykes and dams were required to maintain natural flow conditions. Since 1890 the average level of Lake St. Clair has been 574.77 feet. The average discharge through this river system since 1900 has been 175,100 cubic feet per second.

Lake Erie

Lake Erie is the fourth largest of the Great Lakes in area but is the shallowest. The length of the vessel track from Amherstburg at the mouth of the Detroit River to Fort Erie at the head of the Niagara River is 233 miles. It

is 57 miles across at its widest point, from Port Talbot to Ashtabula. The water-surface area is 9,940 square miles of which 4,950 are in Ontario and 4,990 are in the United States.

The maximum recorded depth of the lake which occurs a few miles off Long Point is 210 feet. The vessel track, which follows closely the International Boundary, is generally more than forty feet deep except in the area west of Point Pelee, where dredging is required to maintain a minimum navigation depth of 21 feet. The average level of the lake from 1860 to 1952 has been 572.34 feet. The lowest monthly mean level was 569.39 feet in 1935 and the highest monthly mean level was 574.80 feet occurring in 1862.

The length of the Ontario mainland shoreline is 310 miles. From Amherstburg to Point Pelee the shoreline is characterized by low sand and clay bluffs that are subject to a moderate rate of erosion through wave action. There is evidence that the eroded material from this section is carried eastward by the lake currents and is largely responsible for the formation of Point Pelee. The same process has led to the formation of Point Aux Pins. This hooked sand point is created from the eroded material of the clay and sand shore cliffs immediately to the west of it. The eighty mile stretch of shoreline from Point Aux Pins to Long Point is composed of clay and sand bluffs rising to a maximum height of 100 feet between Port Burwell and Port Rowan. The shoreline of Long Point consists mostly of unstable sandy beaches backed by marshes. From Port Dover to Fort Erie, rock outcrops occur which have protected the shoreline and have helped to maintain sandy beaches.

The drainage basin of Lake Erie is 34,680 square miles of which 11,110 are in Ontario and 23,570 are in the United States.

The mean annual precipitation for the period 1890 - 1951 on the Lake Erie drainage basin is 34.37 inches,

compared to a mean of 31.18 inches for the entire Great Lakes basin.

Niagara River

The Niagara River flows in a northerly direction from the east end of Lake Erie, descending 10½ feet in a distance of 22 miles to the rapids above Niagara Falls. Here it drops about 50 feet in a short length of the river above the Falls and then plunges sheer over the Falls for a drop of 172 feet. From the foot of the Falls an additional descent of 93 feet occurs in the eight miles of rapids to Lewiston. In the last six and a half miles to Lake Ontario the water drops slightly over six inches. The total drop in elevation from Lake Erie to Lake Ontario is 326.46 feet. Since 1900 the average discharge through the Niagara River has been 194,400 cubic feet per second. The average diversion in that time through the Welland Canal has been 2,600 cubic feet per second which makes a total average outflow from Lake Erie of 197,000 cubic feet per second. The natural control of the outflow from Lake Erie through the Niagara River is a rock ledge at the head of the Niagara River near Fort Erie.

Lake Ontario

Lake Ontario has the smallest surface area of the Great Lakes. This area, including the Niagara River below the Falls and the St. Lawrence River to the head of the Galop Rapids, is 7,540 square miles of which 3,980 are in Ontario and 3,560 are in the United States. Although it is smaller in water-surface area than Lake Erie, it has a larger capacity. Eleven and a half per cent of the entire capacity of the Great Lakes is in Lake Ontario compared to nine and a half per cent in Lake Erie. The distance from Burlington at the west end to Kingston at the head of the St. Lawrence River is 193 miles. It is widest between Trenton and Rochester, a distance of 53 miles. The deepest recorded point is 778 feet where the bottom is about 525 feet below sea level.

From 1860 - 1952 the average level of the lake has been 245,89 feet. The maximum monthly mean in this period was 249.12 feet occurring in May of 1952. The minimum monthly mean for this period was 242.55 feet occurring in 1934.

The length of the Ontario mainland shoreline on Lake Ontario is 330 miles. The shore from the Niagara River to Hamilton is a line of long smooth curves without prominent headlands or deep bays. The cliffs in this section are not more than 30 feet high and are composed entirely of clay and sand except for an outcrop of shale near Grimsby. A mile west of Grimsby the shale disappears and clay forms cliffs from 12 to 24 feet high as far as Winona. From Winona to Stoney Creek the shore cliffs give way to low lying sandy beaches subject to inundation during periods of high water. Crescent and Van Wagners Beaches are located in this section of the shoreline. A prominent sand bar, four miles long and from 300 to 1,200 feet wide closes off the western extremity of Lake Ontario, forming Burlington Bay.

From Hamilton to the Humber River the shore cliff is comparatively uniform with variations up to 30 or 40 feet high. West of Oakville there are outcrops of shale with few good beaches, while east of Oakville the cliff is almost entirely composed of sand, silt, and clay, with better beaches.

The Toronto shoreline is low lying, much of the waterfront property being created from sand and earth dredged from the lake. The great sandyhook which forms Toronto Island is the outstanding feature of this shore. The greater part of Toronto Island is at an elevation of 249 feet and consequently suffers very severely in periods of excessive high water such as that of May, 1952, when the lake rose to 249 feet 8 inches.

East of Toronto, at Scarborough, sand and clay bluffs rise almost perpendicularly as much as 300 feet above the lake. This section of the shore cliff has contributed

A typical clay shore cliff on the Niagara Fruit Belt. Rates of erosion are often in terms of the number of rows of peach trees that fall into the lake.

(N. Mousley)

The spectacular clay and sand bluffs at Scarborough extend for nine miles east of Toronto reaching a height of 300 feet then sinking gradually till they end at the valley of Highland Creek.

much beach-forming material to off-shore sand bars and to the great hook of Toronto Island. East of Scarborough the bluffs become gradually lower, and the shoreline is characterized by smooth curves with no prominent headlands or bays.

East of Port Hope there is a transition in the shoreline from low clay and sand bluffs to outcrops of shaly limestone. On the west coast of Prince Edward County the limestone is overlain with sand. On the east coast of Prince Edward County and east of Belleville, the limestone is exposed on the shoreline right down to Kingston, where it gives way to granitic pre-cambrian rocks.

The drainage basin of Lake Ontario is 34,630 square miles of which 15,920 are in Ontario and 18,710 are in the United States.

The mean annual precipitation on the Lake Ontario drainage basin for the period 1890 - 1951 is 33.56 inches.

The St. Lawrence River

The transition from Lake Ontario to the St. Lawrence River commences at Kingston and extends downstream for forty miles through the region of the Thousand Islands almost to Brockville. In this section the flow is almost imperceptible. From Brockville to the Galop Rapids, just below Prescott the river falls less than one foot. The total fall from Lake Ontario to Prescott, a distance of 55 miles, is only two feet.

Four miles below Prescott at Johnstown, the International Rapids section commences and continues downstream for 48 miles to the head of Lake St. Francis which is five miles below the City of Cornwall. Two and a half miles downstream from Johnstown the river enters the Galop Rapids which are divided by Galop Island. The rock ledge extending across the river in this vicinity acts as the natural control of the outflow from Lake Ontario. From Johnstown to the foot of the Galop Rapids there is a total fall of about ten feet.

From the foot of these rapids at Cardinal to the Rapide Plat at Ogden Island there is a fall of ten and one half feet, and a further drop of eleven and one half feet through the four mile length of the Rapide Plat at Morrisburg. From Morrisburg to Weaver's Point, a distance of seven miles, the narrowing river channel creates strong currents and falls about five feet. The river then flows through a fairly wide reach with relatively little drop for three miles to the head of Croil Island where the Farran Point Rapids fall four feet. From the foot of these rapids to the head of the Long Sault Rapids at Dickinson Landing, a distance of four miles, the current is moderate and with little fall. From Dickinson Landing to Cornwall, a distance of nine miles, there is a fall of 46 feet, 30 of which are concentrated in the Long Sault Rapids and the remaining 16 feet in the river below. At mean river stage there is a total fall through the International Rapids section of 92 feet.

East of Port Hope there is a transition in the shoreline from low clay and sand bluffs to cliffs of shaly limestone such as these which occur at Presqu'ile

On the coast of Prince Edward County and east of Belleville the limestone is exposed on the shoreline as far as Kingston.

On the east coast of Prince Edward County sand dunes overlie the shallow limestone.


DRAINAGE BASINS
OF THE
GREAT LAKES
AND
GENERAL DATA
DRAINAGE AREA ADDED BY THE OGOKI AND LONG LAC DIVERSIONS
SCALE MILES
MINNESOTA
WISCONSIN
MICHIGAN
ONTARIO
QUEBEC
NEW YORK
PENNSYLVANIA
OHIO
INDIANA
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
MICHIPICOTEN
SAULT STE MARIE
MONTREAL
OGDENSBURG
KINGSTON
TOLEDO
CLEVELAND
DRAINAGE BASIN DATA
SUPERIOR 43,330 80,800 73,200 75,000 28.82
HURON 47,970 72,420 101,900 175,100 31.52
ERIE 11,110 34,880 21,900 197,000 34.37
ONTARIO 15,920 34,830 40,000 237,000 33.56
1 Ogoki - 5,545 sq. miles
2 Long Lac - 1,630 sq. miles
Total - 7,175 sq. miles
GENERAL DATA ON THE GREAT LAKES
Elevation in Feet above Sea Level 1860 - 1952
Dimensions
Maximum
Minimum
Average
Area
SUPERIOR
HURON
ERIE
ONTARIO 249.12 (1952) 242.55 (1934) 245.88 7,540 330

PLATE NO I

NOTE - Scales distorted to show relationships between levels of the lakes and falls in the connecting rivers.

PROFILE OF THE GREAT LAKES AND CONNECTING RIVERS

PLATE NO. 2

2

THE GREAT LAKES IN ONTARIO'S DEVELOPMENT

1. Historical

Ever since the white man came to this continent the Great Lakes have played an important role in its development. After settlement began along the St. Lawrence River the activities of the French on Lake Ontario and Lake Erie were at first limited because the Iroquois and Neutrals who dwelt in in these regions were passively hostile. Like their Huron allies, the French were largely restricted to the "back routes" to Lake Huron via the Ottawa, Nipissing and Trent Rivers and the "Toronto Portage". Even before the Iroquois became hostile about 1650, there was fairly free movement of missionaries and traders along these routes and the Jesuit Fathers were able to carry large quantities of heavy goods to Ste. Marie, near Midland, probably by way of the Trent or the "Toronto Portage".

After 1651 the French were excluded by the Iroquois from Lake Ontario altogether and were hard put to maintain the difficult and dangerous route to Lake Huron. It was not till Fort Frontenac was founded in 1673 and La Salle began his settlement there that Lake Ontario really became accessible to the French. By 1779 La Salle was able to build a vessel above Niagara Falls and begin navigation on the Upper Lakes. In the same year a French post was established as far west as Duluth. From 1710 to 1759 the contest between the French and British for control of the Great Lakes led to the establishment of many forts and posts between Fort Frontenac and Sault Ste. Marie. In 1762 after seven years of war, control passed to the British.

On the outbreak of the American Revolutionary War in 1775 the Great Lakes were the major line of communication

for the Empire Loyalists into Upper Canada. Once hostilities were ended in 1783, the organized settlement of Upper Canada was begun. Most of the Loyalists were assembled at Lachine and moved up-river to distributing centres at Cornwall and Kingston, where they were given locations along the St. Lawrence and around the Bay of Quinte. Some went on by Lake Ontario direct to the Niagara Peninsula. Niagara and Detroit were also location centres and the surveyors could not keep up with the demand for lots on the front of the townships. The rapid development could hardly have taken place without the lake navigation which made it easy to distribute and provision the settlers.

The war of 1812 with the United States was to a great extent decided by action on the Great Lakes and the interruption of water communications at this time led to the occupation of Georgian Bay and influenced the direction of settlement when the great migration from Europe began after 1816. The British Government adopted a policy of opening up the inland lines of communication and built canals on the Ottawa and Rideau to by-pass the St. Lawrence Rapids. A steadily increasing volume of traffic now began to and from Montreal by the Lakes. A considerable number of immigrants came by way of New York and Niagara. Merchandise was also shipped out by this route, especially after the Erie Canal provided a direct outlet from Lake Erie. A Canadian outlet was soon provided by the Welland Canal and this led directly to the canalization of the Grand River below Brantford for barges. It was, however, not till the late 1840's that proper canals were made on the St. Lawrence and the Welland Canal improved so that "first class" vessels could carry their cargoes to Lake Huron without transshipping.

The great development of the export trade in lumber especially to Europe was directly dependent on the Great Lakes. The transportation of square timber and ships' masts was almost entirely by water. Square timber was built into large rafts at assembling points along the lower lakes and transported in this way to Montreal and Quebec.

After the railway building of the 1850's the water route to the east became less essential to the southern part of Ontario, but it still remained the chief outlet for the North-west where development was just beginning. The railways encouraged rather than checked the local traffic on the lower Lakes by providing better transportation to the ports When this local traffic began to decline in the late seventies, the produce of the prairies was already moving down the Great Lakes. Since the building of the transcontinental line of the Canadian Pacific Railway in 1881, this long distance traffic has steadily increased in volume and may be expected to grow still greater. On the other hand the traffic from the smaller ports had dwindled almost to nothing by the beginning of this century and such inland canals as had been completed have fallen into disuse.

2. The Major Uses of the Waters of the Great Lakes

(a) Navigation

The Great Lakes and connecting canals form the greatest inland waterway in the world both from the standpoint of traffic volume and distance. During the last ten years traffic passing through the Sault Ste. Marie canals has been approximately twice as great as that passing through the Panama Canal. In this period the waterborne commerce on the Great Lakes had exceeded 200 million tons per year. Coal, iron, grain and petroleum products make up the bulk of the freight carried.

The controlling navigation depths on each of the connecting waterways between the lakes are as follows:

St. Marys River.	25 feet
St. Marys Locks.	31 feet
St. Clair - Detroit.	25 feet
Welland Canal.	25 feet
Welland Locks.	30 feet
St. Lawrence River, down to Prescott.	24 feet
St. Lawrence River, Prescott to Montreal	14 feet
St. Lawrence River, Montreal to the sea.	30 feet

Navigation on the Great Lakes is affected to a major degree by even small changes in lake levels. A reduction in the water level by even a few inches in the naturally shallow sections of the shipping routes means a severe reduction of the cargo tonnage. For maximum operating efficiency vessels load

One of the major uses of the waters of the Great Lakes is the development of hydro-electric power. The expanding needs for power in the Province have necessitated the building of a new generating station on the Niagara River. In the right background is the Sir Adam Beck Niagara Generating Station No. 1 of the Hydro-Electric Power Commission of Ontario; on the left is the building of the Hydro's Sir Adam Beck Niagara Generating Station No. 2

as deeply as their design and draft will permit. The tons of cargo per inch of immersion of Great Lakes freighters varies from 38 tons to 100 tons. In other words vessels must carry from 38 - 100 tons less per load for each inch reduction in draft due to lack of adequate depths of water.

During high lake stages greater depths are afforded in the shallow connecting waterways and canals, so that small changes in lake levels affected only a few of the largest freighters. As the levels of the lakes fall a progressively larger percentage of the freighters is affected by these small fluctuations until, when the lakes reach low stages virtually the entire fleet of the Great Lakes freighters is seriously affected.

The Corps of Engineers, United States Army, report that a decrease of 0.1 feet in the levels of the lakes decreases the tonnage of the annual carrying capacity of the iron ore fleet as follows:

When lake levels are at low water datum	- 144,200 tons
When lake levels are at mean stages	- 125,000 tons
When lake levels are at stages that prevailed in 1951	- 3,480 tons

(b) Power

Hydro-electric power developed from the Great Lakes is of major importance to the economy of the Province. Ontario power developments on the Great Lakes system are located on the St. Marys River and on the Niagara River.

The outflow from Lake Superior which averages 73,200 cubic feet per second falls about 22.5 feet most of which is concentrated at the St. Marys Falls on the St. Marys River. Two Canadian companies and three American companies have a total installed capacity of 34,000 and 76,000 horsepower respectively.

The Niagara River with an average flow of 194,400 cubic feet per second falls 326 feet from Lake Erie to Lake Ontario, 315 feet of which are concentrated at the Falls and the rapids above and below the Falls. The total installed capacity of hydro-electric generating stations on both the New York and Ontario sides of the Niagara River is 1,732,000 horsepower, with a planned installed capacity of an additional 2,900,000 horsepower.

On the Ontario side of the Niagara River there are five power generating stations with a total installed capacity of 1,136,000 horsepower. On the New York side there are two stations with a total installed capacity of 596,000 horsepower. The Hydro-Electric Power Commission of Ontario is now building the Sir Adam Beck - Niagara Generating Station No. 2 which will have in 1957 an installed capacity of 1,200,000 horsepower. The Corps of Engineers, United States Army has recommended the construction of a generating station with an installed capacity of 1,700,000 horsepower to utilize the United States share of flow of the Niagara River. It is of the opinion that the ultimate development of power from the flow of the Niagara River would require the regulation of the outflow from Lake Erie.

The proposed development of power on the International Rapids section of the St. Lawrence River is estimated to yield 2,200,000 horsepower which would be divided equally between Ontario and the United States.

(c) Water Supply and Sanitation

A dependable and abundant supply of fresh water is an asset that has contributed in no small way to the development of the Province. In 1952, 107 municipalities in the Province secured either all, or part of their water from the Great Lakes. It is estimated that there are one and three quarter million people within these municipalities who use this service for their water supply. Adequate water supply is a limiting factor in many of the inland municipalities in South-western Ontario for industrial expansion and it is conceivable that pumping systems from the Great Lakes will be developed more and more in the future to meet these needs.

The waters of the Great Lakes are also used for sanitary purposes. Sixty-three municipalities in the Province serving 1,628,000 people have sewer systems discharging into the Great Lakes. Twenty-eight of these municipalities serving 434,000 people discharge sewage into the Great Lakes without treatment of any type. Because of their tremendous storage capacity pollution has not been a problem other than in the narrow connecting waterways between each of the lakes. In October, 1950, the International Joint Commission issued a

report on the Pollution of Boundary Waters, which dealt with the degree of pollution and which recommended remedial measures for the boundary waters between Lake Superior - Lake Huron, Lake Huron - Lake Erie, Lake Erie - Lake Ontario.

(d) Recreation

The beaches and waters of the Great Lakes are a recreation resource of great importance to this Province and will become of even greater significance as population and urbanization increase. The planning and management of this resource, as in other natural resources should be guided by the conservation principle of "the greatest use for the greatest number of people for the greatest length of time".

In the disposition of provincial crown lands the policy that has been in existence since 1947 provides the setting aside of two lakefront lots in ten for public use. While this will meet the needs on north shore of Lake Huron and on Lake Superior where crown lands are still available it cannot alleviate the pressure for more public lakefront lands on the older settled sections of the Great Lakes.

During the past ten years there has been an unprecedented residential and industrial development along the Great Lakes shoreline particularly on Lake Ontario, Lake Erie and the east shore of Lake Huron. The result has been that much shoreline has been pre-empted by private individuals so that the public is being crowded into more and more restricted sections.

Within 25 miles of the shorelines of Lakes Ontario, Erie and Huron there are over two and a half million people in the Province, all of whom are users or potential users of the beaches of the Great Lakes. The demand for lakefromt property for recreational uses has been made even stronger by Americans who are buying lakefront lands in Ontario. This type of development is particularly well advanced near border crossing points.

Although the Province owns in most cases the lands lying between high and low water marks these lands are of no use for recreational purposes unless contiguous to accessible mainland that is publicly owned.

In former years there were sufficient undeveloped lakefront properties to meet the recreational needs of the Province. This situation has now changed. Private development of lakefront properties particularly during the last 10 years, together with an increase in population has meant greater demands for public lakefront properties on the Great Lakes.

(e) Fishing

Commercial fishing in the Ontario waters of the Great Lakes is a big factor in the provincial economy. Fisherman operating in these waters have an investment in nets, boats, freezers, ice houses, wharves and gear of approximately $6,334,000. The industry pays wages to 3,886 men engaged in actual fishing operations. In 1951 these waters yielded over 24 million pounds of fish, the main species being whitefish, blue pickerel and perch. The value of the 1951 catch was $5,895,000.

COMMERCIAL FISHING IN THE ONTARIO WATERS OF THE GREAT LAKES

Lake	Catch lbs.	Value of Catch	Value of Equipment
Ontario	2,410,424	423,539	482,025
Erie	13,144,053	2,892,136	3,521,783
St. Clair	389,118	60,552	93,478
Huron	5,742,154	1,877,727	1,493,397
Superior	2,[illegible],964	[illegible]	[illegible],095
TOTAL	24,536,713	$5,894,731	$6,334,978

The beaches of the Great Lakes are one of the Province's greatest recreational assets. Approximately two million people, which is almost one half of the total population of the Province, live in the municipalities fronting the Great Lakes and its connecting waterways

3

SHORE EROSION & INUNDATION

1. Shore Erosion and Its World Wide Significance

History indicates that shore erosion is by no means a recent problem. On the eastern coast of the Mediterranean are evidences of former towns and villages of the early Phoenicians, which are now eroded away or inundated by the sea. Parts of the southern coast of Italy and Sicily which were famous fishing centres in the 15th and 16th centuries are now under water or washed away by the incessant action of waves. In more recent times, the extensive dyking and protective works of the Dutch, not only to prevent erosion but also to reclaim land from the sea is well known. The reclamation and protective works in the Zuider Zee are proof of their enterprise and ingenuity.

In England some stretches of the Yorkshire coast have receded more than a mile since the Norman conquest and two miles since the time of the Romans. Cliffs near Dover on the English Channel are receding at the rate of 15 feet per year and the Goodwin Sands, now a shallow submarine bank and a graveyard for ships, was formerly an island. Heligoland, off the mouth of the Elbe, at one time was being eroded so rapidly that it would have disappeared entirely had not erosion been checked by protective works.

On the Atlantic shores of the United States and the Gulf of Mexico erosion has become an increasingly important problem as these areas become urbanized or developed for industrial purposes, By 1930 the loss and damage of property from beach erosion in the United States reached such proportions that the Federal Government established a Beach Erosion Board within the War Department in the office of the

Chief of Engineers of the United States Army, which was charged with conducting research and experimentation on beach erosion problems.

The Atlantic and Pacific shores of Canada are predominantly rocky and for this reason erosion is of minor importance on our sea coasts.

2. Developments in Ontario

As early as 1918 the Ontario Department of Mines in co-operation with the Dominion Department of Public Works undertook a detailed shore erosion and sedimentation study at Point Pelee.* Important studies† were made also by the Ontario Department of Mines in 1936 in relation to the geology of the north shore of Lake Ontario, and of Pelee and adjacent islands. These reports provide much fundamental data on shore structures and erosion in those regions.

The first public recognition of the problems of lakeshore erosion in this Province commenced in 1945 with the formation of the Niagara-Toronto Lakeshore Protective Association. On March 10th, 1948, this organization sponsored a conference on lakeshore erosion which was held in Toronto and which was attended by practically every municipality in the Province bordering on the Great Lakes which has an erosion problem. At this conference the parent organization, which was limited in its scope, was disbanded and a new organization was formed known as The Ontario Shore and Beach Preservation Association. This new organization has the same objectives as its parent organization, but included all municipalities in the Province affected by shore erosion.

As a result of representations made at this conference to the Hon. Dana Porter, Minister of Planning and

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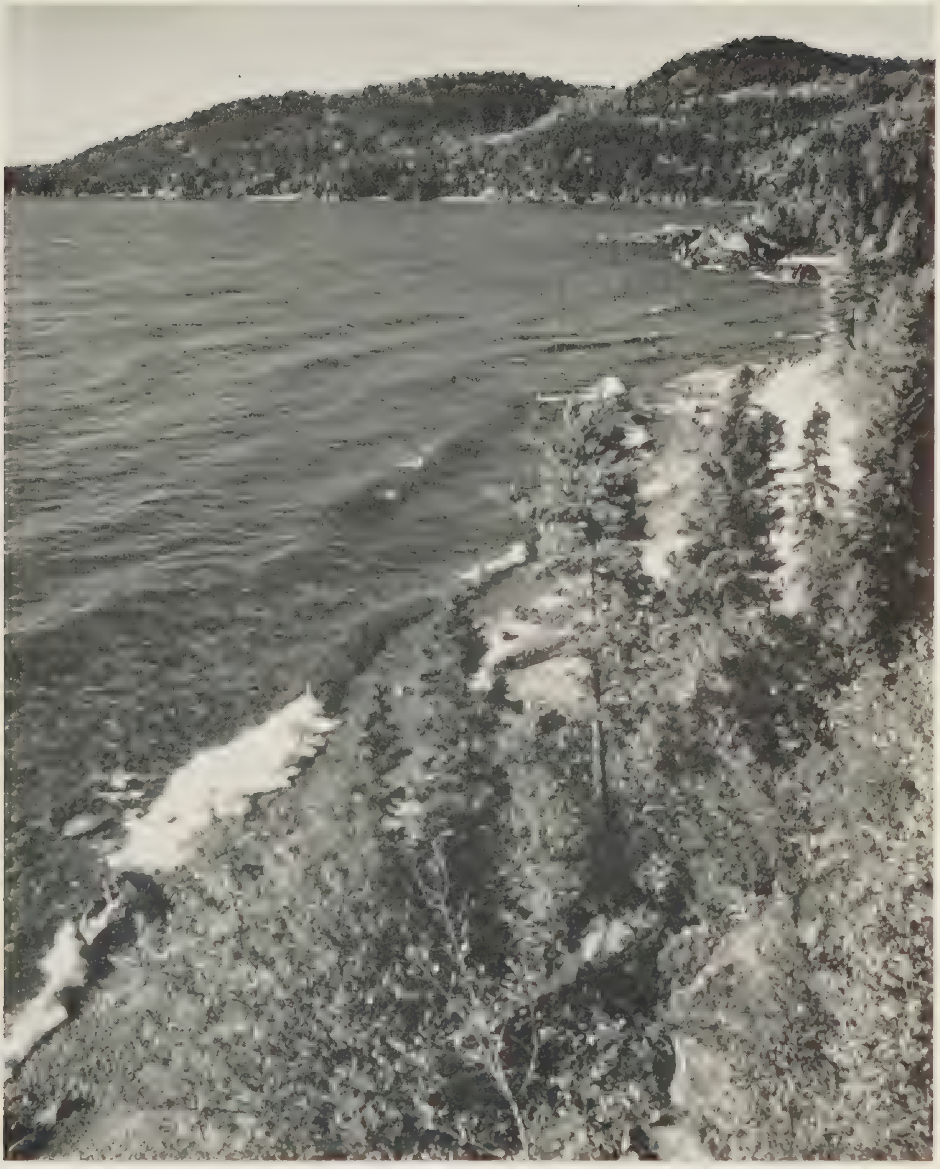
* 42nd Annual Report, Ontario Department of Mines, 1933, Vol. XLII, Pt. II.

† 45th Annual Report, Ontario Department of Mines, 1936, Vol. XLV, Pt. VII.



Since the Ontario shoreline of Lake Superior is predominantly rocky and its lake levels are regulated, damage from erosion and inundation is not of a serious nature

Near Pickering on Lake Ontario the clay shore cliffs are 20-40 feet high. The average rate of erosion in this section for the past 150 years has been 1.21 feet per year.

Development at that time, Dr. G. B. Langford, Professor of Geological Sciences, University of Toronto, was engaged to prepare a report on Lakeshore Erosion in the Province of Ontario. The field work for this has been completed for the whole area and a report covering Lake Ontario from Niagara to Cobourg was published in 1949.

In the report of the Select Committee of the Ontario Legislature published in 1950 a number of recommendations were made on the subject of lakeshore erosion, two of which emphasized the necessity of commencing studies of shore processes and lake currents. This report further indicated that such studies were essential for the proper design and location of protective structures.

In addition to the above, studies on the subject of shore erosion have been made by graduate and undergraduate students of some of our universities.

In the course of its hearings, your Committee was greatly impressed by the number of private citizens most of whom are lakeshore property owners and who, on their own accord, have studied and observed the behaviour of the lakes in so far as they affect beach formation and beach erosion. Fortunately some of these citizens have recorded their observations which will be found useful in compiling a detailed study of the processes of beach erosion and beach formation for all sections of the Great Lakes.

3. Shore Erosion and Inundation in Ontario

Estimates of the extent of erosion and inundation along the shoreline of the lower Great Lakes vary with recurrent changes of water levels and with the criteria set up by various investigators. The mileages given in the following tabulation show the approximate length of stretches of shoreline within which erosion and inundation in recent years has created considerable public alarm and brought much private property into danger of serious loss.

(a)	Lake Ontario - from Prince Edward County to Niagara River	225 miles
(b)	Lake Erie - from Port Maitland to Amherstburg	255 miles
(c)	Detroit River - from Amherstburg to Windsor	20 miles
(d)	Lake St. Clair - the whole of the south shore	40 miles
(e)	Lake Huron - Sarnia to Southampton	130 miles
		670 miles

The relationship of the physical characteristics of the shores of the Great Lakes to erosion and inundation is shown on Plate No. 3.

Your Committee attempted to set forth several representative cases that depict the problem as it was found to exist on Lakes Ontario, Erie, St. Clair and Huron. The fact that accurate data on rates of erosion are not known for all sections of the shoreline visited and are thus not included in the Committee's report, does not in any way diminish the amount of very real damage that is being suffered in other sections.

Since the Ontario shoreline of Lake Superior is predominantly rocky and its lake levels are regulated, damage from erosion and inundation is not of a serious nature.

(a) LAKE ONTARIO

(1) Port Hope Area

Erosion has been moderate to severe immediately east of the Port Hope harbour jetties at the mouth of the Ganaraska River. One property in particular in this section has lost 135 feet in 13 years. The town engineer estimates that the average annual rate of erosion in this area over the last 64 years is one and a half feet.

(2) Pickering and Scarborough Townships

Data which determine the rate of erosion by Lake Ontario in Pickering Township include notes and a map of Augustus Jones (1791 - 1792) who laid out the townships


SHORE CONDITIONS
OF ONTARIO
ON THE
GREAT LAKES
ROCKY SHORE - With no significant erosion, often alternating with sand beaches
CLAY, SAND AND GRAVEL SHORE - Subject to water action
BLUFFS OR SHORE CLIFFS - Subject to erosion
LOW LYING BEACHES AND MARSHES - Subject to inundation
Scale Miles
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
WASAGA BEACH
TORONTO
HAMILTON
PRESCOTT
LAKE ONTARIO
LAKE ERIE

PLATE NO. 3

between the Don and Trent Rivers, a plan of Pickering Township by John Shier in 1854, and the aerial photographs taken in 1942. Measurements from these maps and photographs give the following data:

East Boundary of Pickering Township:

Recession from 1791 to 1854 - 81.44 feet or 1.29 feet per year

Recession from 1854 to 1942 - 94.00 feet or 1.06 feet per year

Average for 151 years is 1.16 feet per year.

West Boundary of Pickering Township:

Recession from 1791 to 1854 - 116.48 feet or 1.85 feet per year

Recession from 1854 to 1942 - 72.3 feet or 0.82 feet per year

Average for 151 years is 1.26 feet per year.

The average for both boundaries of Pickering Township is 1.21 feet per year.

Submissions to your Committee have stated that the rate of erosion and amount of property damage has been increased during the past five years when the lake levels have been higher. The loss has been further aggravated by the extensive residential development at Fairport Beach and Dunbarton shores, which has taken place since 1945. Many former summer cottages which were built close to the waterfront have been converted into permanent dwellings.

In a very comprehensive submission by a lake-front property owner* who has observed the changes at the Scarborough waterfront during the past 25 years, it was pointed out that nature had once established a comparative state of equilibrium along the Scarborough waterfront. Much of the bluffs were wooded and erosion was slight. The shore at the foot of the Bluffs was once littered with glacial boulders weathered out of the banks, and the Bluffs were protected by two sand bars parallel to the shore about two hundred yards out in the lake, on which the heavy waves broke and spent much of their force.

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* H. S. Clark, The Guild Inn, Scarborough.

This witness considered that the first steps toward increased erosion and upsetting this state of comparative equilibrium started a little over 100 years ago. At that time great quantities of sand were taken from the eastern beaches of the city by wagon and in barges for construction in Toronto. The second step was the operation of a number of "stone hookers", heavy hulled vessels which, for over 60 years, gathered up the glacial boulders from the foot of the Bluffs. These were used as crushed stone for building and paving in Toronto. The third, but most important factor of all affecting erosion on the Scarborough waterfront, was the decision to enlarge the Toronto Island and the Toronto waterfront, and to fill in part of Ashbridges Bay. The "Cyclone" and "Tornado" the largest sand suckers in the world, during 1910 to 1914 removed immense quantities of sand and clay from outside Fisherman's Island east of the eastern gap, with the result that within a few years the sand bars off Scarborough Bluffs and the eastern beaches had been seriously depleted, having shifted to fill in the holes in the lake bottom left by the sand suckers. The full force of the waves then broke at the foot of the Bluffs which were now unprotected by boulders with the result that beach and bank erosion was greatly accelerated. These natural barriers having been removed, a series of slides commenced in the Bluffs proper carrying away vegetation and leaving the sand and clay exposed to the erosive effects of surface drainage, seepage, rain and wind.

(3) Toronto Island

The Toronto Island was originally a long peninsula composed of sand bars extending for about two miles in a south-westerly direction. Historical evidence indicates that it was formed gradually over a long period of years by the building up of deposits eroded from Scarborough Bluffs and carried westerly by lake currents. Originally there was no

eastern entrance or gap, as it is now known, to Toronto Bay but in its place was a sand pit which was a ready source of building material.

It is said that a hill of sand which had existed at this place was reduced to near lake level and in 1853 a severe storm washed an opening across at this point. Similar storms enlarged the breach to 1500 feet by 1862. The Federal Department of Public Works in a report made in 1881 recommended the closing of this channel; but this was not acted upon, for, in 1882, construction was started on the Eastern Gap which reduced the channel to a width of 400 feet. This has been kept open ever since and now requires the annual removal of 40,000 cubic yards of sediment which the currents carry into it. In this way the supply of sand which developed the Island and is essential for its natural maintenance has been cut off. The result has been that erosion has increased which, in turn, has necessitated the building of protective structures.

The total area of the Island and its lagoons is 1,280 acres of which the lagoons make up 450 acres. Its chief use is for parks, recreational purposes and summer residences. In recent years, because of the prevailing housing shortage, many of the summer houses have been winterized for permanent use. Approximately 3,000 people live in the 620 houses on the Island. The elevation of most of the Island is approximately 249 feet 6 inches. From the 9th of April to the 22nd of July, 1952, a period of 12 weeks, Lake Ontario was at a level of 249 feet or more, reaching a maximum on May 31st of 249 feet 8 inches. During this time large areas of the Island were inundated. This flooding has resulted in a dislocation of school, shopping, fire protection, and sanitation facilities. Estimates of the extent of damage are not available other than the extra costs incurred by the City of Toronto in restoring bridges, sidewalks and other city property.

Photographic Survey Corp.

The greater part of Toronto Island is at an elevation of 249 feet, 6 inches, and consequently suffers very severely in periods of excessive high water such as that of May, 1952, when the lake rose to 249 feet, 8 inches.

Measurements made by an Ontario Land Surveyor in Lincoln County show that the rate of erosion has been as great as 21 feet per year during the high water stage of 1949-1952.

When your Committee visited the Island on May 14th, at which date the lake level had not yet reached its maximum, the shopping centre on Manitou Road was inundated and almost all of the homes on Centre Island required elevated cat-walks or built up accesses.

The curtailment of the use of the Island parks caused by high lake levels and resulting inundation has meant a loss of revenue to the City. The Toronto Transportation Commission which operates the Island ferry claim a loss of $50,000 in revenue for the years 1951 and 1952, because of reduced passenger traffic in these years of high lake levels.

The protective structures for the Island consist of 1,700 feet of offshore breakwater built in 1922 by the Federal Government at a cost of $200,000, and 6,500 feet of seawall built in 1936 on a fifty-fifty basis by the Federal Government and the City of Toronto at a cost of $282,000. The top of this seawall is at elevation 252 feet above sea level and has not provided the protection required for lake levels exceeding 249 feet. During the high stages in April and May of 1952, the waves broke over this seawall flooding the whole area of the Island behind it. During the same year this wall was raised three feet by the City of Toronto.

(4) Niagara Fruit Belt

The southern shore of Lake Ontario from the Niagara River to Hamilton has been subject to lakeshore erosion of a very serious nature. The land lying between the Niagara escarpment and the lakefront varies in breadth from six miles on the east to less than one mile just west of Grimsby. This relatively small area of approximately 65,000 acres is one of the most productive and valuable areas in Canada for the production of peaches and other fruit. Farmland assessments vary from $100 to $200 per acre, and residential property from $100 to $150 per foot. The Committee has been advised that the value of farm lands in this area is from $1,000 to $1,200 per acre.

Mr. D. G. Ure, an Ontario Land Surveyor at St. Catharines, supplied survey records on the rate of erosion for the townships fronting Lake Ontario in Lincoln County. These data are set out in Table No. 1. They indicate that the easterly townships of Niagara and Grantham, which occupy a more exposed position on the shore, are being eroded more than twice as rapidly as the townships further west. The fact that the eastern shores have more sand and till in their formation than

the western shores, which are chiefly shale, accounts in part for the difference in rate of erosion in this section. It is also noted that the rate of erosion during the past three years when Lake Ontario has been at a high stage has greatly exceeded the rates of erosion prior to 1949. Data on the amounts and rates of erosion since 1932 on Lot 1, Con. I of Grantham Township have been submitted by Mr. Ure and are shown on Plate No. 4.

Farmers who appeared before your Committee spoke in terms of the number of fruit trees that fell into the lake each year. Some had lost as much as two rows of trees in the past three years. Rows are normally planted 22 feet apart. It has been estimated that there has been a total loss from lakeshore erosion of about 2,000 acres from the Niagara Fruit Belt during the past one hundred and fifty years.

TABLE NO. 1

Rate of Shore Erosion in Lincoln County on Lake Ontario

Location	Date	Recession (feet)	Average Recession (ft. per year)
Niagara Township			
Lot 194	1942 - 1950	14	1.7
	1950 - 1952	20	8.0
Lot 187	1939 - 1948	151	17.5
	1948 - 1952	87	21.0
Lot 186	1915 - 1936	162	7.8
	1936 - 1946	138	13.0
Grantham Township			
Lot 1	see detail plan		
Lot 4	1913 - 1949	233	6.5
	1949 - 1952	75	21.0
Lot 7	1912 - 1949	278	7.5
	1949 - 1952	41	12.5
Louth Township			
Lot 2	1916 - 1949	64	1.9
	1949 - 1952	2	0.8
Lot 11	1940 - 1946	5	0.8
	1946 - 1952	18	3.0
Clinton Township			
Lot 20	1928 - 1941	35	2.6
	1941 - 1952	40	4.0
North Grimsby Township			
Lot 5	1947 - 1950	No loss	
	1950 - 1952	9.0	3.6

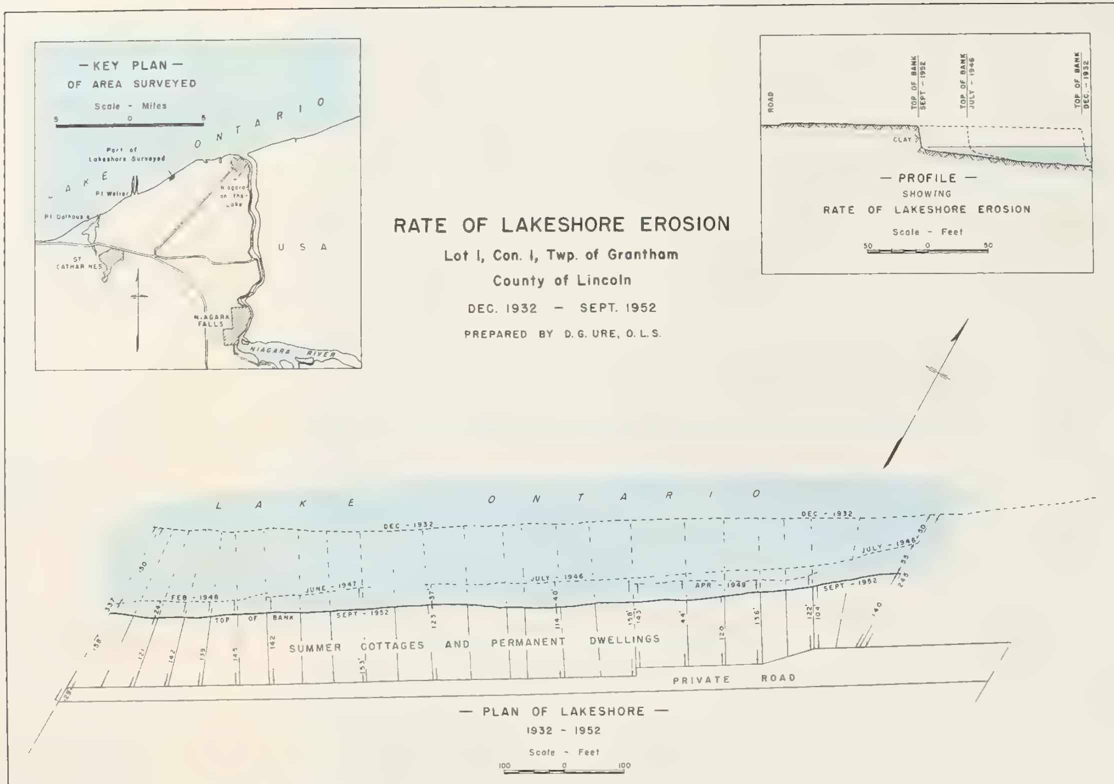
RATE OF LAKESHORE EROSION
Lot I, Con. I, Twp. of Grantham
County of Lincoln
DEC. 1932 — SEPT. 1952
PREPARED BY D. G. URE, O. L. S.
— KEY PLAN —
OF AREA SURVEYED
Scale - Miles
LAKE ONTARIO
Part of Lakeshore Surveyed
Pt Weller
Pt Dalhousie
ST CATHARINES
Niagara on the Lake
U S A
NIAGARA FALLS
NIAGARA RIVER
— PROFILE —
SHOWING
RATE OF LAKESHORE EROSION
Scale - Feet
ROAD
TOP OF BANK SEPT - 1952
TOP OF BANK JULY - 1946
TOP OF BANK DEC. - 1932
CLAY
L A K E O N T A R I O
DEC - 1932
JULY - 1946
JUNE - 1947
FEB - 1948
APR - 1949
SEPT - 1952
TOP OF BANK
SUMMER COTTAGES AND PERMANENT DWELLINGS
PRIVATE ROAD
— PLAN OF LAKESHORE —
1932 - 1952
Scale - Feet

PLATE NO. 4

(b) LAKE ERIE

(1) Long Point to Point Aux Pins

The region of greatest shore erosion on the Ontario shoreline of Lake Erie is the eighty miles from Point Aux Pins to Long Point. The entire shoreline in this section is composed primarily of boulder clay, sand and gravel. Bluffs rise from a height of 40 feet in the west to over 100 feet at points between Port Burwell and Port Rowan in the east. Mr. H. R. Wood of McMaster University conducted an investigation on lakeshore erosion in this section of Lake Erie in 1950 with the assistance of a scholarship granted by the Research Council of Ontario. His data on rates of erosion which are set out in Table No. 2 are based on comparing aerial photographs of the shoreline at the time of study with the shoreline as determined from surveys and surveyors notes made between 1801 and 1845.

TABLE NO. 2

RATE OF SHORE EROSION
FROM
POINT AUX PINS TO LONG POINT ON LAKE ERIE

Township	Height of the bluff (feet)	Average Annual Rate of Erosion Since 1845 (feet)	Average Annual Loss (acres)
Howard	40	1.	.7
Orford	70	2.	1.9
Aldborough	70 - 100	3.5	5.5
Dunwich	100 - 110	3.4	4.7
Southwold	110 - 115	5.4	4.1
Yarmouth	120 - 130	6.8	7.6
Malahide	110 - 130	4.0	4.2
Bayham	50 - 100	6.4	6.0
Houghton	100	6.5	7.9
TOTAL			42.6

"Going, going . . . . ." Cropland in Houghton Township, Norfolk County succumbed to Lake Erie a month after it was seeded down. The average annual loss of lakefront land in this township since 1845 is estimated to be as high as 6.5 feet per year. In 100 years almost 800 acres from this township have gone into the lake.

(2) Essex County

Data supplied by the clerk of the Township of Colchester South, and shown on the following engineer's plan indicate that the rate of erosion in front of the village of Colchester has been approximately 2.5 feet per year during the last 100 years. Here again submissions to your Committee state that although actual measurements of erosion have not been made during the past two years of high water, there is no doubt that it has been more rapid than the long term average.

The high water stage of Lake Erie has also had very damaging effects on many of the drainage schemes in this County. Much of the valuable agricultural land in Essex County has been reclaimed from the lake by the construction of dykes and subsequent removal of the water by pumping. These works have been endangered by high water. In addition, many of the pumps which maintain the water levels in the drainage ditches have had to be replaced with more expensive equipment to handle the additional water coming in from the lake. The accompanying picture of the outlets of one of these drains in Colchester Township shows how the effectiveness of these schemes can be seriously reduced by high lake levels.

(c) DETROIT RIVER

A factor which has aggravated the damage to inundated areas along the Detroit River has been the wash created by the heavy traffic of boats. The effect of this wash in periods of critically high river levels was serious enough to require that boats travel at reduced speeds in sections of this River.

(d) LAKE ST. CLAIR

The problem on Lake St. Clair is primarily one of inundation resulting from high water. The entire south shore of Lake St. Clair is low lying, so that high lake levels cause flooding over large areas of land. Serious property damage has been sustained by residents of the municipalities of

Riverside, Tecumseh and Belle River during the high lake levels of 1951 and 1952.

The risk of damage and privation caused by inundation is becoming more serious every year as lake frontage is being further developed, and the tendency grows to convert summer homes into permanent dwellings. With summer homes, no serious difficulty was experienced, as residents merely stayed away until conditions were favourable, but with permanent homes, the effects of inundation are extremely serious.

It appears that residences have been constructed in the past with no study given to the possibility of inundation. In the Belle River district the extremely marshy lands appear to have been reclaimed by surface draining into ditches, which causes serious difficulty for many miles inland, when high lake levels impede the flow of the drainage water. When high winds carry lake water over the rim of the shore it is actually trapped, and having no outlet, must stay there until it seeps into the soil or is evaporated into the air.

(e) LAKE HURON

Sarnia to Bayfield

There is little data available on the rate of erosion on the Lake Huron shoreline. Near Bright's Grove in Lambton County, the county road was moved back in 1914 to a distance of forty feet from the edge of the shore cliff as it existed at that time. When the Committee visited this section of the shoreline in 1952, the shore cliff had cut back at some points to the very edge of the road.

From Grand Bend to Bayfield shore erosion has caused severe damage at points to farmlands and summer cottages. Accurate data on the rates of erosion in this section are not available.

4. Factors Affecting Shore Erosion

(a) Waves

Beaches are dynamic, not static. Their build up, maintenance and erosion depends on the relationship between deposition and removal of sand and gravel of which they are composed. Field and laboratory observations have established the fact that wave action is the principal agency of shoreline change. Waves are generated by the action of wind upon the water surface and their magnitude depends on the velocity and fetch of the wind and the depth of water. Waves are a very important factor in beach erosion because of the damage they can cause to all types of shore installations and because they increase the range and rate of active erosion.

The effectiveness of waves as an agent of erosion depends on their supply of energy and the manner in which this energy is expended along the shore. If the offshore slope of the beach is very gentle most of the energy of the waves is spent in breaking on the offshore zone. Where the offshore slope of the beach is steep or where beaches are not present the entire energy of the waves is expended on the bluffs thus increasing the rate of erosion.

When lake levels are high the waves are able to break closer to the bluffs hence increasing the rate of erosion. On the other hand, when lake levels are low, the depth of water over offshore sand bars is often sufficiently reduced so that the major force of the waves is spent breaking on these bars and not on the beaches.

(b) Currents

Very little is known of the currents in the Great Lakes. The only publication on this subject prior to 1952 is an Atlas of the United States Weather Bureau issued in 1895. It was based on the release of paper bottles and their subsequent recovery. Although the conclusions of this report are not considered to be too reliable it is the only


SURFACE CURRENTS OF THE GREAT LAKES
AS DEDUCED FROM THE MOVEMENT OF BOTTLE PAPERS
DURING THE SEASONS OF
1892 - 1893 - 1894
BY THE
UNITED STATES DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
COLLINGWOOD
GODERICH
CHICAGO
TOLEDO

PLATE NO. 5

Littoral drift entering the Eastern Gap of Toronto Harbour has resulted in reduction of the supply of sand and gravel which was essential for the build up and maintenance of the Toronto Island Authorities state that 80 per cent of the littoral drift is carried in the currents shoreward of the six foot depth.

(G. A. Milne)

The ice along the shores of the Great Lakes is often 10 feet thick and generally provides protection to the shore cliffs from winter storms. During the spring break-up, however, large cakes of ice can have a very damaging effect on shore protective structures. The bluffs at Birchcliff, Scarborough.

complete study that has been made of currents in the Great Lakes. The findings of this study are shown in Plate No. 5. In 1952 the Corps of Engineers, United States Army, made a study* of the currents off the United States shores of the Great Lakes.

Lake currents are of two main types: body currents, which are the general movement of water towards the outlet of the lake, and littoral currents which move in shallow water parallel to the shore. Littoral currents are most important in beach formation. These are set up by waves that strike the shore obliquely and thus give the water a component of motion along the shore. They are important in the redistribution of beach materials. They pick up sand and gravel from one section of a beach and deposit it on other sections when they meet an impediment such as a protected bay, an opposing current, or a spit of land. Artificial means of forcing the littoral currents to deposit some of their loads are effected by such structures as groynes, jetties and piers. The United States Beach Erosion Board has established that eighty per cent of the littoral drift occurs shoreward of the six-foot depth. This depth has, therefore, been selected as the limiting location for the end of groynes.

Observations† of littoral currents in the Great Lakes have indicated that they reach velocities as high as two and three miles per hour. As to the amount of beach-forming materials moved by these littoral currents, the Corps of Engineers, United States Army, estimated that the annual rate of littoral drift along the Illinois waterfront on Lake Michigan to be as high as 90,000 cubic yards.

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* Corps of Engineers, United States Army - Preliminary Report on Property Damage on the Great Lakes Resulting from Changes in Lake Levels, June, 1952.

† Johnson, D. W. Shore Processes and Shoreline Development. Kindle, E. M. 42nd Annual Report, Ontario Department of Mines.

Studies of lake currents, particularly the littoral currents, have been lacking in the Ontario waters of the Great Lakes and it is of fundamental importance in the design of sound beach protective measures that they be undertaken immediately.

Your Committee therefore recommends:

THAT SINCE STUDIES OF LAKE CURRENTS HAVE BEEN LACKING IN THE ONTARIO WATERS OF THE GREAT LAKES AND SINCE AN UNDERSTANDING OF THESE CURRENTS IS OF FUNDAMENTAL IMPORTANCE TO SOUND BEACH PROTECTIVE MEASURES, AND SINCE THE GAUGING AND SOUNDINGS OF THE GREAT LAKES IS NOW BEING CARRIED ON BY THE DOMINION GOVERNMENT, THE GOVERNMENT OF ONTARIO THROUGH THE DEPARTMENT OF PLANNING AND DEVELOPMENT ENTER INTO AN AGREEMENT WITH THE GOVERNMENT OF CANADA TO UNDERTAKE STUDIES OF CURRENTS IN THE GREAT LAKES.

(c) Ice Action

The pile up of ice along the shores of the Great Lakes has, in general, a beach protective function against winter storm waves. On the other hand, the damaging effects of ice on shore protective structures can be serious. Groynes, breakwaters and seawalls built without adequate consideration of the action of ice may be short lived.

(d) Removal of Sand and Gravel from Beaches and Lake Bottoms

Evidence has been submitted to your Committee regarding the effects of dredging lake bottoms and the removal of sand and gravel from beaches of the Great Lakes. Two operations are cited in support of this, one at Pelee Island in Lake Erie, and the other in the Toronto - Scarborough waterfront on Lake Ontario.

(1) Pelee Island

Prior to 1920 millions of cubic yards of sand and gravel were removed from a sand spit known as Fishing Point which is at the southerly tip of Pelee Island. It is

stated that the Cities of Windsor, Detroit, Toledo and Cleveland used materials from this part of Lake Erie. In 1917 the residents of Pelee Island became alarmed at the very serious erosion on the east side of their island. Since both dredging and erosion were simultaneously in progress in 1917 it was not surprising to some that a relationship of cause and effect was assumed to exist between them. Attempts were then made by the Council of Pelee Island and the Essex County Council to have the removal of sand and gravel from Fishing Point prohibited with the hope that it would reduce the erosion.

Since most of this material was actually being removed from private lands and as there was no existing law to prohibit this removal a suit was entered by the Province of Ontario and the corporation of the Township of Pelee and others against Home Gardener, the owner of the property. After many days of expert testimony, the judgment of His Honour Judge J. Lennox, delivered February 14, 1920, in summary is as follows:

> "Are the injuries complained of attributable to the acts of the defendants (removal of sand and gravel)? As to the expert or skilled witnesses, it is enough to say that what they deposed to, and what they argued, fell far short of convincing me that the dredging operations caused the destruction of the sand banks or bars. Unfortunately for the plaintiffs, it is shown that the erosion of the shore, the cutting away of the banks, the destruction of the highways, and the consequent re-establishment of them further back, were things of frequent occurrence long before the date of the operations complained of, as witness the records of the Municipal Council, the witnesses at the trial, and the establishment of protective works on the west side of the Island. While the plaintiffs have failed for want of proof, their belief was not irrational and their attempt under the circumstances was not unreasonable. I do not think it is a case for awarding costs to the defendants and the action will be dismissed without costs."

Although the case of Pelee Island was lost in court, concurrently with their bringing the action at law, representation was renewed to the Government of Ontario for legislation which would give them the protection they desired. Accordingly an Act to amend the Beach Protection Act was

introduced in 1920 to prohibit the taking, or carrying away in any vessel, or otherwise transporting by water, any sand, gravel or stone from the bed, beach, shore or waters of Lake Erie, Lake Ontario or Lake Huron, without a licence authorized by the Lieutenant-Governor-in-Council. Acting on the requests of the Island residents the government refused to issue a licence for dredging off Fishing Point and operations were stopped.

It is interesting to note that the same spit known as Fishing Point which was dredged away until it measured only a distance of fifty feet in 1919 had extended to a length of more than two thousand feet by 1933. It would appear that the materials, instead of giving Pelee Island relief from erosion, were once again deposited by waves and currents to form this sand spit, which is of no value as protection against erosion. To further emphasize the soundness of the 1920 judgment, in 1950 a request was made to the Province of Ontario by the Council of the Township of Pelee, by resolution praying that study be given to another removal operation if some of the royalties could be applied to shore protection. Following up this request, test loads of material were removed, and suitable quantities were not found to be available.

(2) <u>Toronto - Scarborough</u>

In 1927 the Township of Scarborough which is adjacent to the east boundary of the City of Toronto claimed that, as a result of dredging in the vicinity of Toronto Island by the Toronto Harbour Commission for the purpose of developing Sunnyside Beach and other sections of the Toronto waterfront, the sand bar in front of the westerly portion of the township disappeared. It was claimed that this sand bar was already seriously depleted by the operations on the sand bar itself by the "Tornado" and "Cyclone" sand suckers from 1910 - 1914 already referred to, and that this latest dredging

operation near the Toronto Island resulted in the complete loss of the sand bar. Scarborough Township stated in their objection to the Toronto Harbour Commission that this offshore sandbar was a natural barrier on which the major force of the waves was spent thus protecting the highly vulnerable cliffs at the Scarborough waterfront.

The Toronto Harbour Commission claimed that there was no evidence of any increase in erosion at Scarborough after their dredging operations off the Toronto Island and that they were not prepared to admit that anything they had done by way of dredging had contributed to the erosion at Scarborough. Furthermore the Toronto Harbour Commission stated that since the port and harbour of Toronto, as defined by statute, extended one mile out into the lake the Commission was entitled to carry on, within this area, any works it might think proper. Then followed seven years of low lake levels and the case was not taken to court.

(3) Studies of the United States Government

Studies made by the United States Beach Erosion Board to determine the possibility of nourishment of beaches by littoral deposition of sand, indicated that there was a haphazard movement in depths of 35 - 40 feet but there was no consistent onshore or offshore movement at these depths.

The United States Corps of Engineers made similar studies in the vicinity of Erie Harbour on Lake Erie and Rochester on Lake Ontario with sand placed in depths of 20 feet. Soundings taken over a period of 2 to 3 years following placement of low mounds of sand in the lake bottom indicated some shifting and levelling off but no appreciable onshore movement. These studies indicate that material at depths of over 17 feet is not likely to be carried ashore, but they are not complete enough to indicate at what depth extensive movement of material does occur.

(4) Policies of the Great Lakes States

The regulation of commercial sand and gravel dredging by the States bordering the Great Lakes is becoming consistently more restrictive. The policy of four of the States fronting the Great Lakes on the removal of lake bottom materials is as follows:

New York

Sand and gravel dredging is prohibited in Lake Erie but allowed in Lake Ontario. A permit is required only for Lake Ontario.

Pennsylvania

There are no restrictions at present other than the securing of a permit. A Bill has been tabled in the Legislature to prohibit dredging within three miles of the shore.

Ohio

Dredging is permitted in a few restricted areas in the vicinity of Fairport, Vermillion and Toledo and such operations may be conducted only beyond the 7-mile limit from shore.

Michigan

The riparian owner has exclusive right to remove sand or gravel from the bed of the lake lying in front of his lands extending outward to 1,000 feet from low water mark on Lakes Michigan, Huron and Superior; 500 feet out on Lakes St. Clair and Erie and 100 feet on the channel of the St. Clair Flats. A permit is required for all dredging operations.

Your Committee was informed by the United States Corps of Engineers that the removal of sand or gravel directly from the beaches for commercial purposes is prevented whenever possible in all states fronting the Great Lakes but that State and Federal laws are ineffective if the removal is confined entirely to sand and gravel from above low water mark.

(5) The Ontario Policy

The policy of the Province of Ontario with regard to the removal of sand and gravel from the beaches and lake bottoms of the Great Lakes is embodied in the Beach Protection Act of 1920. This Act provides that no person shall remove any "sand, earth, gravel or stone from the bed, bank, beach, shore or waters of any lake, river or stream within the province" without a licence. A licence is never granted without an examination first being made by the Department of Mines for the purpose of ensuring that the stability of the beaches and the rate of shore erosion will not be affected by such operations.

The Department of Mines, which is responsible for the administration of this statute, has no control over operations by private individuals or municipalities when the material is for their own use. When this Act was redrafted in 1946, there was no provision for such unlicensed removal, but this amendment was added before the Bill passed the House, at the instigation of the members of the Public Bills Committee. The reason for this provision being added was, that inasmuch as farmers and others had always been able to remove gravel from the lakeshores for their own use, it would be a hardship if this privilege was suspended.

It is the opinion of your Committee that everyone removing material from shores or beaches should be required to obtain a licence so that the Government may exercise control of all of these operations. If necessary, a provision could be written into the Act allowing a bona fide resident or a municipality to take a specified amount of material free of charge, at the same time requiring them to hold a licence to do so. In this way an examination could be made in each case to determine whether such operations would be injurious to adjoining properties or to the shoreline generally.

Your Committee therefore recommends:

THAT THE BEACH PROTECTION ACT BE AMENDED TO PROVIDE THAT EVERYONE WHO WISHES TO REMOVE SAND OR GRAVEL FROM THE BEACHES OR BEDS OF THE GREAT LAKES BE REQUIRED TO OBTAIN A LICENCE, IN ORDER THAT THE PROVINCE MAY EXERCISE CONTROL OVER ALL OF THESE OPERATIONS.

The total amounts of material removed under licence by dredging and beach operations from 1947 - 1951 are given in the following table.

TABLE NO. 3

SAND AND GRAVEL REMOVED UNDER LICENCE
BY
DREDGING AND BEACH OPERATIONS 1947 - 1951

	CUBIC YARDS				
	1947	1948	1949	1950	1951
Lake Ontario	236,270	347,416	383,293	331,500	359,889
Lake Erie	238,895	233,369	254,742	218,722	[illegible]7,[illegible]65
St. Clair River	35,485	31,525	20,962	24,692	10,441
Lake Huron	20,119	17,143	10,510	13,515	7,784
Lake Superior	134,687	60,355	42,200	44,316	38,461
TOTAL	665,456	689,808	711,717	632,745	623,801

The royalty on this material is between ten and twenty cents a cubic yard and produces a revenue to the Province of approximately $85,000 per annum.

Although it has been urged that all dredging operations for the removal of lake bottom and beach materials for commercial purposes should be suspended for two to five years in order to determine the effects of these operations on beach formation, your Committee does not fully concur in this view. If operations were stopped just as the lakes commenced to recede, thus forming better beaches, it might be assumed

by those not familiar with such factors as precipitation, evaporation, wind and wave action that the prohibition of the removal of material was responsible for the improvement. On the other hand, if the lake levels continue to rise higher it could be said that the suspension of these operations had had no effect on beach formation.

In the light of the policies adopted by the States fronting the Great Lakes and the evidence submitted in the matter of restricting sand dredging, your Committee is of the opinion that the policy of the Government of Ontario does not go far enough in providing protection for the riparian owners on the Great Lakes. It therefore recommends:

THAT STUDIES BE MADE BY THE DEPARTMENT OF PLANNING AND DEVELOPMENT TO DETERMINE THE MINIMUM DEPTH OF WATER AND THE MAXIMUM DISTANCE FROM SHORE THAT DREDGING OPERATIONS* CAN TAKE PLACE WITHOUT HARMFUL EFFECTS, AND THAT STUDIES BE CONDUCTED ON ALL EXISTING AND PROPOSED DREDGING OPERATIONS TO DETERMINE THEIR EFFECTS ON SHORE EROSION.

The Beaches and River Beds Act of 1912 provides that thirty or more ratepayers may petition their municipal council for an application to the Municipal Board permitting the ratepayers to remove sand and gravel from the shore or bed of any lake, river, stream or creek within the township. The Municipal Board may not authorize such a permit if such removal may cause injury to or interfere with, in any way, the adjoining lands. Your Committee was informed that no application has ever been made under this statute. However, since shore erosion must be considered a regional and not a local problem it is conceivable that a permit granted under this Act may not be in the interests of regional protection of the shore and beach and may conflict with the enforcement of the Beach Protection Act.

Your Committee, therefore recommends:

THAT THE BEACHES AND RIVER BEDS ACT OF 1912 BE REPEALED.

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* This does not refer to dredging operations for the purpose of maintaining navigation channels.

Lakefront property owners in Lincoln County claim that the dredging of offshore sand bars has depleted their beaches of sand and gravel, thereby increasing the rate of erosion. There is a need for studies on the effect of sand and gravel dredging on shore erosion

4

LAKE LEVELS

In almost all of the submissions to your Committee, the suggestion was made that the levels of the Great Lakes should be controlled and regulated, so that damage by erosion and inundation could be kept at an absolute minimum. The purpose of this chapter is to (1) describe the factors which affect lake levels, (2) to indicate the importance of these factors, (3) to explain how the levels of Lake Superior are regulated and (4) to make observations on the probable effects of the proposed St. Lawrence River power development on the levels of Lake Ontario.

The levels of the Great Lakes vary from year to year, month to month, day to day and even hour to hour. The yearly and monthly variations are due to increases or decreases in the amount of water in the lakes while the short term fluctuations are due to surges of the lake water - a piling up of water in one portion of the lakes and a withdrawal from other parts. The most important change from the point of view of shore erosion is one which produces a substantial rise in the level of the lakes, and maintains that level for a sufficient time for wave destruction to take place. The short term fluctuations, or surges, are of minor importance in this regard. The important ones are those brought about by major additions to the amount of water in lakes.

1. Recording of the Levels of the Great Lakes

Fragmentary records of the levels of some of the lakes are available as far back as 1815, but the accuracy of these earlier records cannot be relied upon. Continuous and reasonably reliable records have been kept since 1860.

Improvements in equipment and methods of taking records increased their accuracy and since 1900 they can be considered as precise.

In Canada the records of lake levels are provided by the Canadian Hydrographic Service of the Department of Mines and Technical Surveys. In the United States this work is the responsibility of the United States Lake Survey which is a section of the Corps of Engineers of the United States Army. These two services of both countries co-operate by a complete exchange of information.

All elevations are quoted in feet above mean sea level, in terms of the United States Lake Survey datum of 1903 adjustment. The records are used to determine average lake levels which are expressed as daily mean level, monthly mean level and yearly mean level. When referring to mean lake levels it is important that the period for which the mean was calculated is stated.

The first self-registering gauge on the Canadian side of the lakes was installed in 1906, at Collingwood, on Georgian Bay. By 1910 the Canadian Hydrographic Service had one or more such gauges operating on each of the lakes. At present there are sixteen self-registering gauges providing year-round records of lake levels from Port Arthur to Kingston.

The present distribution of gauging stations on the Great Lakes by the Canadian Hydrographic Service and by the United States Lake Survey is shown on Plate No. 6.

2. Long Term Variations in Lake Levels

The monthly mean levels from 1860 - 1952 of each of the lakes are shown on Plate No. 7.

According to the summary of levels provided by the Canadian Hydrographic Service covering the period from 1860 to 1952 the maximum range in monthly mean levels in this period was 4.09 feet on Lake Superior, 6.24 feet on Lake Huron, 5.41 feet on Lake Erie and 6.57 feet on Lake Ontario.


LOCATION OF GAUGING STATIONS
ON THE
GREAT LAKES
INSTALLED AND OPERATED BY
THE CANADIAN HYDROGRAPHIC SERVICE
THE CORPS OF ENGINEERS - U. S. ARMY
CANADIAN GAUGING STATIONS
UNITED STATES GAUGING STATIONS
Scale Miles
25 0 25 50 75 100
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
PORT ARTHUR
TWO HARBORS
KEWEENAW LOWER ENTRANCE
MARQUETTE
Above CANADIAN LOCK
Below CANADIAN LOCK
CALUMET HARBOR
POINT EDWARD
PORT STANLEY
GROSSE POINT
WINDMILL POINT
KINGSTON
OSWEGO
BLACK ROCK
PLATE NO. 6

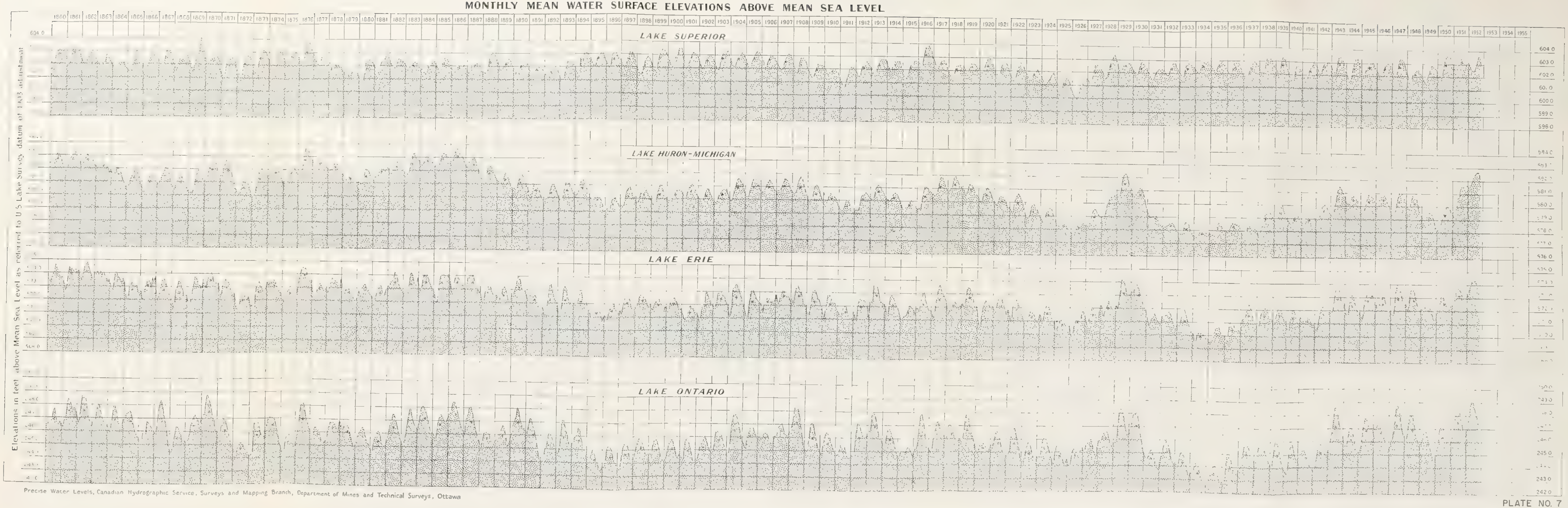
MONTHLY MEAN WATER SURFACE ELEVATIONS ABOVE MEAN SEA LEVEL
LAKE SUPERIOR
LAKE HURON-MICHIGAN
LAKE ERIE
LAKE ONTARIO
Elevations in feet above Mean Sea Level as referred to U.S. Lake Survey datum of 1935 adjustment
Precise Water Levels, Canadian Hydrographic Service, Surveys and Mapping Branch, Department of Mines and Technical Surveys, Ottawa

PLATE NO. 7

Table No. 4 shows the range in levels from the highest monthly mean to the lowest monthly mean for the period 1860 - 1952 on each of the lakes.

TABLE NO. 4

VARIATIONS IN MONTHLY MEAN LEVELS (1860 - 1952)
(in feet)

	Highest Monthly Mean	Lowest Monthly Mean	Range
Lake Superior	604.08 - Sept. 1869	599.99 - Apr. 1926	4.09
Lake Huron	583.66 - July 1876	577.42 - Feb. 1934	6.24
Lake Erie	574.80 - July 1862	569.39 - Feb. 1935	5.41
Lake Ontario	249.12 - June 1952	242.55 - Dec. 1934	6.57

The yearly mean levels vary irregularly and not in any discernible cycles. In general, years of high level follow years of high precipitation and years of low precipitation are followed by low levels. Table No. 5 shows the range in levels from the highest yearly mean to the lowest yearly mean for the period 1860 - 1952 on each of the lakes:

TABLE NO. 5

VARIATIONS IN YEARLY MEAN LEVELS (1860 - 1952)
(in feet)

	Highest Yearly Mean	Lowest Yearly Mean	Range
Lake Superior	603.15 (1951)	600.72 (1926)	2.43
Lake Huron	583.08 (1886)	577.71 (1934)	5.37
Lake Erie	574.07 (1862)	569.90 (1934)	4.17
Lake Ontario	247.84 (1952)	243,41 (1935)	4.43

Many attempts have been made to discover cycles in high and low years of lake levels, but in reviewing the studies which have been made by scientists on this subject, it does not appear to this Committee that the changes in yearly mean levels follow any regular pattern or are in any way predictable.

In Essex County high lake levels have reduced the effectiveness of municipal drains when their outlets run into the lake.

Your Committee would like to emphasize the unreliability of statements tending to show the existence of any regular pattern of high and low water years, and the danger that would be consequent to riparian owners if such assumptions should be accepted.

3. <u>Seasonal Variations in Lake Levels</u>

The levels of all the Great Lakes show a seasonal variation throughout the year, the high levels being reached in summer or early fall and low levels in late winter. The following tables show the range in monthly mean elevations in one calendar year for the period 1860 - 1952, and the occurrence of maximum and minimum monthly elevations.

<u>TABLE NO. 6</u>

RANGE IN MONTHLY MEAN ELEVATIONS IN ONE CALENDAR YEAR
FROM 1860 - 1952
(in feet)

	Maximum	Minimum	Average
Lake Superior	2.67 (1869)	0.51 (1929)	1.04
Lake Huron	2.23 (1871)	0.38 (1941)	0.98
Lake Erie	2.57 (1917)	0.75 (1911)	1.19
Lake Ontario	3.65 (1867)	0.71 (1920)	1.46

<u>TABLE NO. 7</u>

THE OCCURRENCE OF MAXIMUM AND MINIMUM MONTHLY ELEVATIONS
FROM 1860 - 1952

	Average Maximum Month	Average Minimum Month
Lake Superior	September	March
Lake Huron	July	February
Lake Erie	July	February
Lake Ontario	June	January

On occasion the seasonal variations between winter low and summer high have departed widely from the above figures. Likewise there have been years in which the lakes have reached their highest and lowest levels at times which differ widely from the established pattern.

Marked variations from the average seasonal range indicate a major change in the water supply and if the condition persists it will bring about a period of high water or low water frequently referred to as high or low stages. Such stages may last for one season only or may continue for several years.

4. Factors Affecting Long Term and Seasonal Variations in Lake Levels

(a) Meteorological

The two meteorological phenomena, precipitation and evaporation, are the dominant factors controlling the levels in the Great Lakes. Precipitation includes water in the form of rain and snow.

The precipitation falling on the lake surfaces has a direct effect in raising their levels. During the period 1890 - 1951 the average annual precipitation on each of the Great Lakes was as follows: Lake Ontario 33.56 inches, Lake Erie 34.37 inches, Lake Huron 31.52 inches, Lake Superior 28.82 inches. When one considers that the lake surfaces total almost one third of the entire drainage basin of the Great Lakes the effect of precipitation directly on the lakes themselves is an important factor in raising or lowering their levels.

Precipitation on the land areas of the Great Lakes basins has a less direct effect on their levels. Much of the precipitation on the land never reaches the lakes, a large proportion being evaporated or used by growing vegetation. The condition of the land at the time of precipitation determines to a great extent the amount of water that will ultimately

reach the lakes. If precipitation occurs when the land is dry, much water will enter the soil to replenish the ground water storage, or will be held in the countless small lakes and swamps within the drainage basin. When this drainage basin is "wet" that is, the land is holding a relatively high amount of water and the small lakes are full, much of the precipitation will run off directly into the streams and rivers emptying into the Great Lakes.

Only when precipitation is persistently above average or persistently below average for a number of years does it raise or lower lake levels. Excessive precipitation in only one year following a period of average or below average precipitation has little, if any, effect on the levels of the Great Lakes as much of the water is retained in the soil, and the natural storage areas of small lakes and swamps. Similarly only one dry year following years of average or above average precipitation has little effect in lowering the lakes as the land will deplete its storage into the Great Lakes to maintain their levels.

During the period from 1890 to 1951 the average annual precipitation on the Great Lakes drainage basin according to the Canadian Hydrographic Service was 31.18 inches. Table No. 8 shows the total precipitation for each year in this period and the amount it was above or below this long term average. From 1900 to 1936, both inclusive, the total of average precipitation would have been 1,154 inches; however, the total of actual precipitation in this period was 28 inches less than this amount. In 1936 and in the four years previous, all the lakes, except Superior, which is artificially controlled, were experiencing levels considerably below their averages.

From 1937 - 1947, both inclusive, the total of average precipitation would have been 343 inches; the total actual precipitation was 16 inches greater. In 1947 high stages were being experienced on all of the Great Lakes.

(London Free Press)

Groynes have been rendered obsolete and erosion has been greatly accelerated by high lake levels
Orchard Beach near Port Stanley on Lake Erie

TABLE NO. 8

PRECIPITATION ON THE GREAT LAKES DRAINAGE BASIN

ANNUAL AVERAGE AND DEPARTURE FROM 1890 - 1951 AVERAGE *

Average Annual Rainfall 1890 - 1951 - 31.18 Inches

Year	Precipitation in inches	Departure	Year	Precipitation in inches	Departure
1890	34.34	+ 3.16	1921	30.64	- 0.54
1891	29.70	- 1.48	1922	30.71	- 0.47
1892	32.52	+ 1.34	1923	28.43	- 2.75
1893	34.12	+ 2.94	1924	31.43	+ 0.25
1894	30.31	- 0.87	1925	28.18	- 3.00
1895	27.77	- 3.41	1926	34.43	+ 3.25
1896	30.88	- 0.30	1927	31.78	+ 0.60
1897	31.39	+ 0.21	1928	33.87	+ 2.69
1898	32.24	+ 1.06	1929	31.65	+ 0.47
1899	30.12	- 1.06	1930	25.12	- 6.06
1900	31.33	+ 0.15	1931	30.03	- 1.15
1901	30.03	- 1.15	1932	32.06	+ 0.88
1902	31.58	+ 0.40	1933	29.32	- 1.86
1903	32.31	+ 1.13	1934	27.44	- 3.74
1904	30.22	- 0.96	1935	29.15	- 2.03
1905	32.49	+ 1.31	1936	28.17	- 3.01
1906	30.50	- 0.68	1937	34.16	+ 2.98
1907	29.90	- 1.28	1938	33.16	+ 1.98
1908	28.24	- 2.94	1939	29.77	- 1.41
1909	30.83	- 0.35	1940	32.55	+ 1.37
1910	27.06	- 4.12	1941	31.99	+ 0.81
1911	31.30	+ .12	1942	34.42	+ 3.24
1912	31.48	+ 0.30	1943	32.70	+ 1.52
1913	32.41	+ 1.23	1944	31.06	- 0.12
1914	28.65	- 2.53	1945	35.67	+ 4.49
1915	32.01	+ 0.83	1946	29.91	- 1.27
1916	33.68	+ 2.50	1947	33.39	+ 2.21
1917	29.48	- 1.70	1948	30.26	- 0.92
1918	30.59	- 0.59	1949	32.15	+ 0.97
1919	30.08	- 1.10	1950	35.66	+ 4.48
1920	28.99	- 2.19	1951	37.22	+ 6.04

* Data from the Canadian Hydrographic Service, Ottawa.

The high stages of 1947 were followed by average precipitation in 1948 - 1949, and excessive precipitation in 1950 - 1951. During these two latter years alone there was a total of 10 inches of precipitation higher than the 1890 - 1951 mean of 31.18 inches. The result was that in 1952 the lake levels rose to elevations even higher than the high stages of 1947, and in the case of Lake Ontario, higher than any previous record.

It is interesting to note that during the two years 1950 - 1951 the precipitation on the Great Lakes drainage basin averaged 17 per cent above the 1890 - 1952 average; in the same two years the loss of water to evaporation from the drainage basin was eight per cent less than average.

Your Committee attaches considerable importance to the above data and submits that this combination of persistence in above mean precipitation that has been building up since 1937 and accentuated in 1950 and 1951, together with a decrease in the past two years of eight per cent in the amount evaporated from the drainage basins, is undoubtedly the major cause of the 1952 high water stages on the Great Lakes.

(b) Tilting Movement of the Earth's Crust

During the retreat of the Pleistocene ice sheet the water levels in the basins of the Great Lakes were much higher than they are now. The old shorelines are plainly visible in many places and can be followed for many miles. The last high-water phase in the Ontario basin has been named Lake Iroquois, whose shoreline has been described in detail by Dr. A. P. Coleman.* At Hamilton it stands at 362 feet above sea level; at Scarlett Road in York Township it stands at 421 feet; and at Quays, north of Port Hope, it is 557 feet above sea level. Since this continuous shoreline must have been

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* Coleman, A.P. Lake Iroquois. Ontario Department of Mines Annual Report. Volume XLV, Part VIII, pp. 1-36, 1936.

level when formed, it is obvious that the land toward the northeast has risen considerably. A similar condition is found in the basin of Lake Simcoe where the Algonquin shoreline stands at 724 feet near Schomberg and at 900 feet near Washago.*

Old shorelines in the Lake Erie area are much more nearly horizontal, and geologists claim that it is near the hinge line, that is, the line along which crustal movement does not take place. Present day deductions indicate that the hinge line runs from slightly south of Duluth, crosses the entrance to Green Bay, passes close to Goderich and on through the Niagara Peninsula. North from this hinge the land is rising and south of this line the land is subsiding.

The natural consequence of this tilting is that the lakes with outlets north of the hinge line, such as Superior and Ontario, tend to become deeper and flood their southern or south-western shores relative to the amount their outlets are raised, while the lakes with outlets south of the hinge line, such as Huron-Michigan and St. Clair, tend to have their general level lowered relative to the amount their outlets are depressed.

Changes in water - land relations along the perimeters of the Great Lakes due to the tilting movement of the earth's crust, provide a very debatable and complicated subject.† In the opinion of Mr. C. A. Price, Chief of the Precise Water Levels Section of the Canadian Hydrographic Service, Ottawa, the data set out in Table No. 9 are the rates per 100 years at which the water - land relations are changing along the perimeters of the Great Lakes due to movements of the earth's crust, as evidenced by water level relations during the thirty year period 1920 - 1949.

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* Goldthwaite, J. W. An Instrumental Survey of the Shorelines of the Extinct Lake Algonquin and Nipissing in Southwestern Ontario. Geol. Survey of Canada Memoir 10, 1910.

* Johnson, W. A. The Trent Valley Outlet of Lake Algonquin and the Deformation of the Algonquin Waterplane in Lake Simcoe District, Ontario. Can. Geol. Survey - Museum Bulletin 23, 1916.

* Deane, R. E. Pleistocene Geology of the Lake Simcoe District, Ontario. Can. Geol. Survey Memoir 256, 1950.

† Moore, Sherman, Tilting of the Earth's Crust, Military Engineer, May - June, 1922.

† Crustal Movement in the Great Lakes Area. Bull.U.S.A. Vol. 59, p. 697, 1948.

† Gutenberg, B. Tilting Due to Glacial Melting. Journal of Geology, July - August, 1933.

TABLE NO. 9

CHANGES IN WATER - LAND RELATIONS PER 100 YEARS

Location	Water Encroaching on Adjoining Land In Vertical Feet	Water Receding from Adjoining Land In Vertical Feet
Lake Superior		
Michipicoten Harbour	-	0.71
Port Arthur	-	0.38
Marquette	0.25	-
Duluth	0.65	-
Lake Huron-Michigan		
Thessalon	-	1.02
Mackinaw City	-	0.70
Collingwood	-	0.76
Goderich	-	0.29
Harbor Beach	-	[illegible]
Milwaukee	0.34	-
Calumet Harbor (Chicago)	0.48	-
Lake Erie		
Buffalo	-	-
Port Colborne	-	-
Port Stanley	0.11	-
Cleveland	0.26	-
Lake Ontario		
Kingston	-	-
Cape Vincent	-	-
Oswego	0.18	-
Toronto	0.64	-
Port Dalhousie	0.33	-

Calculations based on these figures show that the rate of tilt per hundred miles per century would be approximately: 0.67 feet for Lake Superior, 0.62 feet for Lake Huron, 0.34 feet for Lake Michigan, 0.22 feet for Lake Erie and 0.73 feet, the greatest, for Lake Ontario.

Several important conclusions derive from this line of evidence:

1. The rate of tilting is very slow but apparently constant. If continued long enough it would eventually, but in the very distant future, cause the Great Lakes to drain southward towards the Mississippi.

(Windsor Star)

The entire south shore of Lake St. Clair was subject to inundation by the high water stage in 1952 and considerable damage was caused. A main street in Riverside is under 12 inches of water in April of 1952.

2. Harbours on the north shores of the upper lakes are becoming shallower while those on the southern shores of the same lakes and on the lower lakes are becoming deeper.

3. The gradual change of the water - land relation on the lakes through crustal tilting, while admittedly slow, is a factor which must be recognized.

(c) Storage

The tremendous storage capacity of the Great Lakes is an important factor in stabilizing their levels. Because they are interconnected, this storage capacity exercises an equalizing influence on the levels of each other. This means that any artificial additions or subtractions of water do not immediately affect their levels.

The late Mr. A. J. Matheson,* of the Department of Resources and Development, calculated that an additional discharge of 30,000 cubic feet per second over and above the normal regulated run-off from Lake Superior if maintained for five consecutive months would lower the lake level by 0.445 feet. It would cause a rise of only 0.168 feet in Lake Ontario after 19 or 20 months. The following table taken from his pamphlet explains the effect of this additional discharge as and when it reaches the lower lakes.

TABLE NO. 10

THE EFFECTS OF ADDITIONAL DISCHARGE FROM LAKE SUPERIOR ON THE LEVELS OF THE LOWER LAKES

Lake		Total effect in feet of depth	Maximum monthly mean discharge in cubic feet per second	Percentage of total flow of 150,000 or 30,000 c.f.s. for five months
Superior	In the 6th month	-0.445	30,000	100 %
Huron	After 6 months	+0.286	4,750	3.16%
Erie	" 14 "	+0.172	3,650	2.43%
Ontario	" 19 or 20 "	+0.168	3,375	2.25%

* The Effect of Natural Storage, A.J. Matheson, Pamphlet 22 - 1 - 39.

While the run-off and levels vary primarily with the amount of precipitation and evaporation, the equalizing influence of the large storage capacity of the lakes themselves enables them to retain a fairly uniform rate of discharge, and is a remarkable form of natural regulation.

(d) Ice Jamming

The jamming of the ice floes in the narrow channels of the connecting rivers of the Great Lakes, reducing their discharge capacity, backs up water in the immediate upper lake and thus raises its level. The only data available on the actual effects of this ice jamming on lake levels are those given by the United States Corps of Engineers, who state that the level of Lake Huron is about an average of 6 inches higher in the winter than it would be if the St. Clair and Detroit Rivers were always ice free. A similar condition in the St. Lawrence River causes increased storage in Lake Ontario. As this effect takes place only during the late winter and early spring when the lake levels are at their seasonal low stages, this factor has little significance.

5. Factors Affecting Short Term Variations in Lake Levels

It has been observed that long-period variations in levels are primarily due to the changing relationships between precipitation, evaporation and run-off.

Short term variations are caused primarily by winds, differential barometric pressures, and tides. They are responsible for surges of the lake water - a piling up of water in one portion of the lake and a withdrawal from another. These variations are superimposed on the existing general levels and cause pronounced peaks in periods of high stages and excessive low ebbs in periods of low stages.

The Corps of Engineers of the United States Army is of the opinion that the magnitude of these short term variations has no relationship to the general lake levels and may be as great during high stages as in low stages, although

(Globe and Mail)

The risk of damage and privation caused by inundation and storms is becoming more serious every year as lake frontage is being further developed. Long Branch on Lake Ontario, March, 1952

A main line of the Canadian National Railways near Oshawa has required protection.

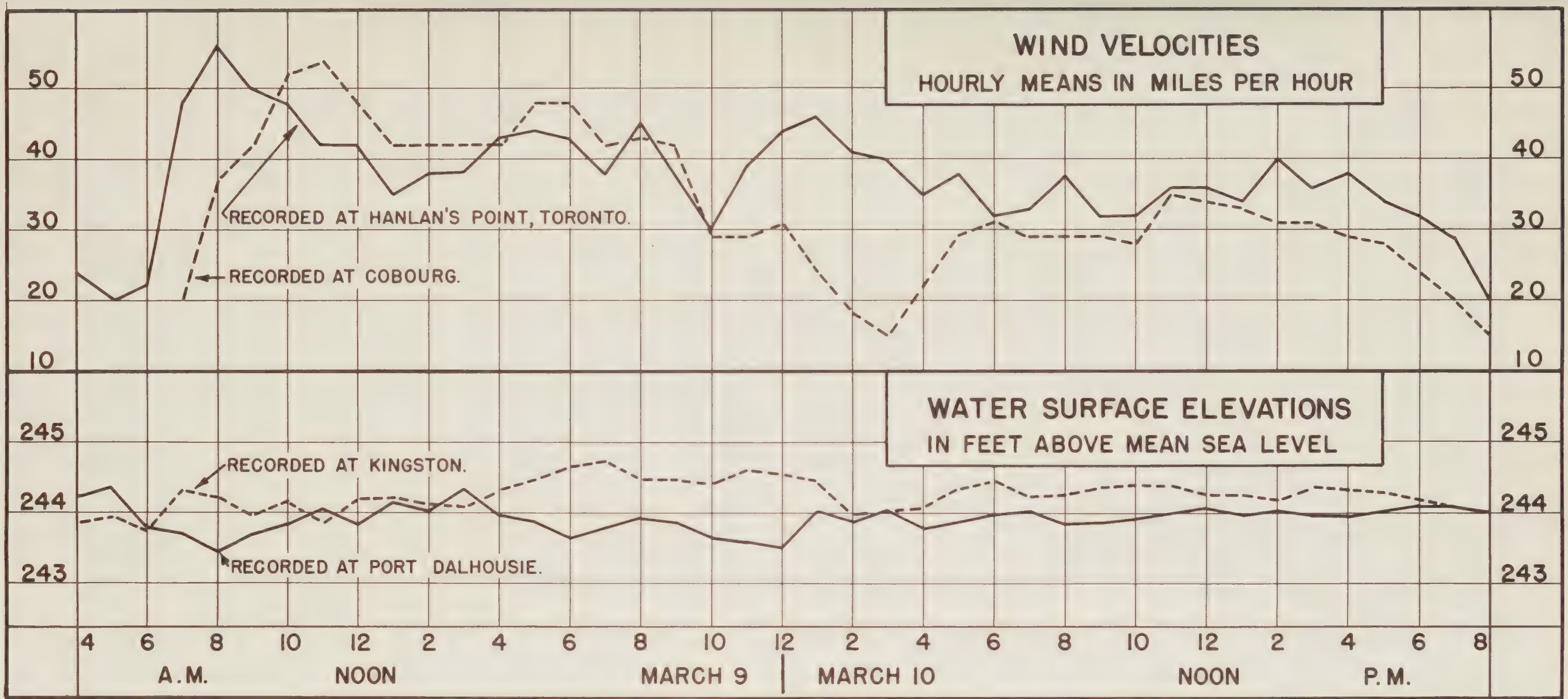
there is reason to believe that the frequency of occurrence . greater at high stages than at low. Evidence before the Committee indicates that these short term variations are more frequent and more intense on the shallow lakes such as Erie, than on the deeper lakes.

(a) Wind

Wind affects the level of all the Great Lakes by building up levels on the leeward shore and lowering them on the windward shore. It is well known that a wind storm will cause a movement of surface water. As the surface water piles up on the shore, there will be a compensating flow in the opposite direction below the surface. In a shallow lake such as Lake Erie, the return flow is restricted and the wind-blown water may cause an appreciable rise of the level. Irregularities of the shore will accentuate this. There are two recognized east-west storm paths which pass over the Great Lakes. The northerly, which is the weaker, passes parallel to and north of the axis of Lakes Superior and Huron and over north-central Ontario. Wind effects on Lake Superior and Huron are not so great because of the great volume and depth of these two lakes. The more persistent and stronger storm path is located along the axis of Lake Erie, which, being shallow, suffers from very pronounced irregularities of level due to wind.

During a gale from the south-west on December 8, 1927, the wind over Lake Erie reached a velocity of 86 miles per hour piling up the water at Port Colborne and Buffalo 12.15 feet higher than the level of the western end of the lake. In a storm on January 2, 1942, a 50-mile per hour wind over Lake Erie increased the elevation of the lake at Buffalo 13.3 feet higher than at the western end.

The accompanying chart shows the effect of west winds on Lake Ontario levels during a storm on March 9th and 10th, 1947.



EFFECT OF WEST WINDS ON LAKE ONTARIO WATER LEVELS

STORM OF MARCH 9-10, 1947.

The effects of wind on lake levels varies with its direction, force, duration, the distance it has travelled (termed the fetch), the configuration of the shore and the depth of water. The wind not only affects the relative elevations at different points on the lake but also causes significant changes in the amount of discharge from Lake Erie into the Niagara River. Variations of 100,000 cubic feet per second between calm and storm periods from the normal of 194,400 cubic feet per second have been recorded. During a storm on December 7, 1907, over Lake Erie, a pile-up was created at Buffalo which increased the discharge to the Niagara River by 200,000 cubic feet per second while during a storm from the east on February 1, 1915, when the level at Buffalo was lowered the discharge was reduced by 90,000 cubic feet per second.

Shore damage may be very severe during such storms because of the excessive height to which the storm waves can reach.

(b) Differences in Atmospheric Pressure

Unbalanced atmospheric pressure on the surface of the same lake causes lake levels to rise and fall in response to the decrease or increase of atmospheric weight. In the area of low pressure the water rises and in the area of high pressure the water level is depressed. The variations of water levels so created are known as seiches. Major seiches of several feet are quite frequent on Lake Superior, occasionally occur on Lake Huron but seldom on Lake Erie and Lake Ontario.

Originally seiches were considered a mysterious phenomenon and were later supposed to be due to tidal disturbances. This is evident from the account taken from Alexander Mackenzie's Voyages of a "phenomenon" which occurred on Lake Superior probably about the year 1780.

> "A very curious phenomenon was observed some years ago at the Grande Portage, for which no obvious cause could be assigned. The water withdrew with great precipitation, leaving the ground dry that had

never before been visible, the fall being equal to four perpendicular feet, and rushing back with great velocity above the common mark. It continued falling and rising for several hours, gradually decreasing until it stopped at its usual height. There is frequently an irregular influx and deflux which does not exceed ten inches, and is attributed to the wind."

On the morning of May 5th, 1952, strong seiches occurred on Lake Huron and variations of almost three feet were recorded by the Goderich and Collingwood gauges.

(c) Tides

Tides are the most important factor affecting the levels of seas and oceans, but on the Great Lakes, due to their relatively small range, they are not significant. However, of all the factors creating fluctuations, those caused by lunar influence are the only ones which are constant even if they are small.

Because the range of tides in the Great Lakes are small they are easily hidden by short period surface disturbances of wind and barometric pressures. Four years of continuous records by the Canadian Hydrographic Service at each of the stations mentioned in Table No. 11 were necessary to establish the following average tidal ranges.

TABLE NO. 11

Lake	Gauging Station	Spring Tide	Neap Tide
Lake Superior	Port Arthur	0.03 feet	0.03 feet
	Michipicoten	0.12 feet	0.06 feet
Lake Huron	Thessalon	0.16 feet	0.08 feet
	Collingwood	0.13 feet	0.06 feet
	Goderich	0.09 feet	0.04 feet
Lake Erie	Port Stanley	0.06 feet	0.05 feet
	Port Colborne	0.11 feet	0.05 feet
Lake Ontario	Port Dalhousie	0.06 feet	0.03 feet
	Toronto	0.05 feet	0.03 feet
	Kingston	0.05 feet	0.05 feet

The spring tides occur during the period of new and full moon, the neap tides on the waxing and waning quarters of the moon. From the table it will be observed that the range of spring tides is approximately twice that of the neap tides and that the tidal effect on the larger and deeper lakes of Superior and Huron is almost twice that of Lakes Erie and Ontario.

To sum up, it can be stated that lunar tides do occur on the Great Lakes but because they are so small and produce only insignificant variations in lake levels they are of scientific interest only.

6. Artificial Factors Affecting Lake Levels

It was natural that many representations at the hearings stressed the importance of the artificial factors that influence lake levels. Since these factors are man-made and thus come within his range of control, a detailed study of each has been made by your Committee in order to evaluate their influence on lake levels.

The most significant of the artificial factors affecting the normal flow of water through the Great Lakes are as follows:

(a) Diversions from the Hudson Bay Watershed
(b) Diversion into the Mississippi River Watershed
(c) Operation of the Lake Superior Regulating Works
(d) Gut Dam

(a) Diversions from the Hudson Bay Watershed

Long Lac

The first diversion of water from the Hudson Bay Watershed commenced in 1937 with the construction of diversion works from the Kenogami River, a tributary of the Albany, into Long Lac. This diversion was for the purpose of floating pulpwood into Lake Superior by way of Long Lac, and was less than 500 cubic feet per second. Diversion of water by the Hydro-Electric Power Commission of Ontario for power

purposes began in January, 1941, and from then until March, 1952, it averaged 1,354 cubic feet per second.

Ogoki Diversion

The diversion from the Ogoki River, a tributary of the Albany, into Lake Nipigon was commenced in July, 1943, for the purpose of developing more power on the Nipigon River and ultimately on the Niagara River. The diversion is effected by means of a 50-foot dam 1700 feet long across the Ogoki River. The impounded water is raised 40 feet, which is sufficient to cause it to flow across the drainage divide of the Great Lakes into South Summit Lake and hence down the Jackfish River to Lake Nipigon. A main diversion channel through the height of land to the South Summit Lake, and a control dam regulates the discharge into the Great Lakes system.

From 1943 until March, 1952, the average discharge from this diversion into the Great Lakes system was 3,598 cubic feet per second. Because there were adequate water supplies for the power stations on the Nipigon River, the discharge into the Great Lakes was cut off entirely in April, 1952. When the Committee inspected these installations in August there was no flow from the control dam to Lake Nipigon. The project is designed to return the entire flow of the Ogoki River to Hudson Bay, when desired.

The total average discharge of the Ogoki and Long Lac diversions from their start until March, 1952, has been 4,952 cubic feet per second. Because of the equalizing influence of the lakes' storage it is estimated that it requires ten years for the full effects of these two diversions to be felt on Lake Ontario, although some effects are felt within 18 months of the commencement of the diversion. Table No. 12 shows the combined effect of the Long Lac and Ogoki diversions on the Great Lakes after the 1st, 3rd, and 10th years.

TABLE NO. 12

THE EFFECT OF THE LONG LAC AND OGOKI DIVERSIONS ON THE GREAT LAKES *

	1st year	3rd year	10th year and maximum effect
Lake Huron-Michigan	1.0 inches	2.9 inches	4.4 inches
Lake Erie	.7 inches	1.9 inches	2.7 inches
Lake Ontario	.7 inches	1.8 inches	2.7 inches

The Long Lac and Ogoki diversions were arranged as an emergency power measure during the war by an exchange of notes between the Governments of Canada and the United States in October and November.

(b) Diversion into the Mississippi River Watershed

The Chicago Sanitary Canal

Since 1845 water has been diverted from Lake Michigan in the neighbourhood of Chicago to enable boats to reach the Mississippi River via the Illinois River. According to the United States Corps of Engineers the amount diverted prior to 1900 averaged 600 cubic feet per second. In 1900 the Chicago Sanitary District completed the construction of a canal from Lake Michigan to the Illinois River for the purpose of diluting and carrying sewage from the metropolitan area down the Illinois River. This diversion gradually increased with the growing needs of the city to 10,010 cubic feet per second by October, 1929, and had the effect of lowering Lake Michigan 6 inches. At the insistence of navigation interests the matter was brought before the United States Supreme Court in 1930 which ruled that "by December 31, 1938, the volume be gradually reduced to a maximum annual average of 1,500 cubic feet per second exclusive of domestic pumpage". Since 1939

* Data from the Canadian Hydrographic Service.

the average total of the diversion has been 3,100 cubic feet per second composed of 1,500 cubic feet per second authorized by the Supreme Court and 1,600 cubic feet per second for domestic pumpage.

The Corps of Engineers, United States Army, estimates that the present total diversion has lowered Lakes Michigan and Huron by 2.7 inches and Lakes Erie and Ontario by 1.8 inches. The maximum effects of this diversion were not felt on Lake Ontario until the end of a ten-year period.

(c) Operation of Lake Superior Regulating Works

The regulation of the level of Lake Superior between the levels of 600.0 and 603.6 feet above sea level raises or lowers the other lakes relative to the amount by which the natural outflow is increased or retarded. In general, the natural flows from Superior are increased when the lower lakes are experiencing seasonal high levels and are retarded when the lower lakes are experiencing low levels. Although it has no permanent effect on the levels of the lower lakes it may accentuate seasonal high and low stages.

(d) Gut Dam and Channel Alterations

In 1903 the Canadian Government built a dam in the St. Lawrence River at the Galop Rapids. The purpose of the dam was to eliminate a cross-current in the River at this point which affected navigation using the Galop canal to by-pass the Galop Rapids and to restore levels in this area which had been lowered by previous deepening of the Canadian Galop channel. The dam and channel changes in this area affected the level of Lake Ontario by altering the stage-discharge relationship at this control point.

The effect of the Gut Dam varied with the level of the lake. Its effect was least during periods of low water and was greatest during periods of high water. The precise effect on Lake Ontario levels of the Gut Dam and the channel alterations in this area is now under study by the International Joint Commission. The increase in Lake Ontario levels from their

combined effects may amount to several inches. The Dominion Government authorized the removal of the Gut Dam in November, 1952, and its removal was completed early in January, 1953.

Summary of Artificial Factors

The effects of the above-mentioned artificial factors upon the levels of each of the lakes are summarized in Table No. 13.

TABLE NO. 13

EFFECTS OF ARTIFICIAL FACTORS ON LAKE LEVELS

Factor	Effect on Lake in Inches		
	Huron-Michigan	Erie	Ontario
Long Lac and Ogoki Diversion	+2.6	+2.7	+2.7
Lake Superior Regulation	Variable Plus or Minus		
Chicago Sanitary Diversion	-2.7	-1.8	-1.8
Gut Dam and Channel Alterations	--	--	*
Total Effect	- .1	+ .9	+ .9

7. Regulation of Lake Levels on the Great Lakes

During the last fifty years, regulation of the Great Lakes has been under study, primarily from the standpoint of enabling the navigation and power resources to be efficiently utilized. As the effects of lake regulation are far reaching and complex, regulation to reduce peak levels and thus minimize erosion and shore property damage has not been fully developed.

Your Committee appreciates the importance of developing the assets of navigation and hydro-electric power on the Great Lakes. However, these developments must be considered in relation to their effects on the 3,000 miles of Ontario's Great Lakes shoreline. Your Committee is of the opinion that it has a responsibility to consider not only navigation and power requirements, but also the requirements of every use that is being made of the Great Lakes.

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* See Page 58, Gut Dam (d), second paragraph.

A submission to the Committee pointed out that a general reduction in the water level by even a few inches in the naturally shallow sections of the shipping routes in the Detroit River and Lake St. Clair sections means a severe reduction of the cargo tonnage in the lake vessels that must pass through this section. It is logical, therefore, that regulation studies have been designed in the past to maintain as high a water level as possible in these sections. It is also in the interests of power development that high levels be maintained in order to develop the maximum amount of electrical energy to meet the expanding needs of this Province and the Lake States.

On the other hand, it is in the interests of lakeshore property protection and for the large and growing proportion of our population who use the beaches of the Great Lakes, to maintain levels as near to the average as possible. The tremendous growth in residential use of lakeshore properties during the past ten years has accentuated the need to reduce the natural range between low and high levels.

Since Lake Superior is the only lake in the Great Lakes system in which the outflow is controlled, and hence its levels are regulated, and since the Committee heard evidence to the effect that one lake was being controlled "at the expense of the others", it was considered advisable to describe the history and method of operating these control works for Lake Superior.

Over a period of years commencing about 1887, and until 1913, work was performed on a number of projects which materially altered flow conditions in the St. Marys River, by reducing the cross sectional area of the river from 16,000 square feet to approximately 8,000 square feet. These structures include the International Bridge, power canals and power houses, navigation and ship canals and locks.

In 1902 the United States War Department set down a series of conditions which the Michigan Northern Power Company would have to conform to in operating its power plant at Sault St. Marie, Michigan. The objects of these conditions were to "hold the waters of the lake and the river under the absolute control of the United States in the interests of navigation". These conditions required that the flow through the canal should be stopped whenever the monthly mean level of Lake Superior at the canal fell below 601.0 feet, and that the flow should be increased to the maximum capacity of the canal if the monthly mean level rose above 603.0 feet. A rule was devised for the operation of the proposed regulating works and a test of the rule for the period 1860 - 1910 indicated that it could be expected to satisfy the required conditions.

In 1906 the International Waterways Commission took up the study of the regulation of Lake Superior and recommended:

1. "As the commission regards the interests of the United States and Canada in the preservation of the lake levels, and in the improvement of the channels and the conservation of the water supply for purposes of navigation as identical and as incapable of efficient protection without joint and harmonious action on the part of the two governments, it recommends that the rules hereinafter set forth be adopted, and that a joint commission be created to supervise their enforcement, or that such powers be vested in the existing International Waterways Commission, subject to such restrictions and reservations as may be deemed advisable."

2. "That the governments of the United States and Canada reserve all water necessary for navigation pruposes, at present or in the future, and the surplus shall be divided equally between the two countries for power purposes."

While the International Waterways Commission was studying proposals for increased power development on the St. Marys River, the International Joint Commission was set up in 1909 expressly:

> "To prevent disputes regarding the use of boundary waters and to settle all questions which are now pending between the United States and the Dominion of Canada involving the rights, obligations, or interests of either in relation to the other or to the inhabitants of the other along their common frontier and to make provisions for the adjustment and settlement of all such questions as may hereafter arise."

In considering the limits of regulation for Lake Superior proposed by the power companies - The Algoma Steel Corporation and the Michigan Northern Power Company - the interests of navigation were taken as paramount to those of power. Navigational interests favour high water level with a small range, as it provides for the maximum cargo load and the least interference with loading and operation of harbours and wharves.

The Commission recognized that the maximum and minimum monthly mean levels of Superior prior to 1913 were 604.8 feet and 600.76 feet which gave a natural range in monthly means of 3.32 feet. With the flow improvement facilities provided by the power companies plus the increased capacity provided in the ship canals it was considered that under normal conditions this natural range between maximum and minimum levels could be reduced to 1.5 feet. The points of lake level determination were changed from the head of the navigation canal at Sault St. Marie to Marquette, but the 1.5 feet range of regulation was maintained and since Marquette was .6 foot higher than the levels at the head of the canal, the permitted range on Lake Superior was established at 602.1 feet and 603.6 feet.

In 1914 the International Joint Commission issued an Order of Approval to the Michigan Northern Power Company and the Algoma Steel Corporation setting down conditions of regulation for the operation of the works, and for the formation of a Board of Control.

> "All compensating works heretofore built and such works built under this Order of Approval shall be so operated as to maintain the level of Lake Superior as nearly as may be between levels of 602.1 feet and 603.6 feet above mean sea level and in such a manner as not to interfere with navigation. The operation of all the said works, canals, head gates and by-passes for the above purposes shall be under the direct control of the board hereinafter authorized which board shall be known as the Board of Control."

The Board of Control provided for in the order was to consist of two members, one, an officer of the Corps of Engineers, United States Army, the other, an officer appointed by the Government of Canada. The present members are Mr. T. M. Patterson, Assistant Chief, Water Resources Division of the Department of Resources and Development, Ottawa, and Col. John D. Bristor, United States Corps of Engineers, Detroit.

The Board of Control, in accordance with the Order of Approval, formulated rule curves to govern the discharge of water from the lake under various conditions obtaining from time to time. The original rule curve known as the "Sabin Rule" was used from 1916 until 1943 when it was replaced by "Rule P-5" based on the improved ratings of the various discharge works. Rule P-5 was used to regulate Lake Superior levels from 1943 - 1951. The extra water supplied to Lake Superior by the diversions from Hudson Bay Watershed rendered Rule P-5 obsolete, and it was superceded in 1951 by the "1949 Rule", which is still applied.

The latter rule was adopted in 1951 and is designed to hold the level of Lake Superior at a wider range of limits than the former rules, namely, from 600.0 to 603.6. It reflects the demand for more water for power. This rule curve was analyzed with regard to the many interests affected and tested against conditions obtaining during the 50-year period 1899 - 1949. From the analysis the Board was satisfied that under operation "Rule 1949" would provide a maximum amount of water for power, and adequate protection to harbours from excessive high water.

To maintain the elevations of Lake Superior within this narrow range of 600.0 and 603.6 abnormally large quantities of water must be released during periods of high water and less than normal amounts during periods of low water. These variations from normal have an effect on all the lower lakes. A report by A. J. Matheson in 1934 stated that an

amount of water sufficient to lower Lake Superior by .445 feet (30,000 cubic feet per second above normal for five months) will cause a rise of .286 feet in Huron six months after the release starts, a maximum of .172 feet on Lake Erie fourteen months after the release starts and a maximum rise of .168 feet on Lake Ontario twenty months after the release starts.

Many regulation studies have been made on Lake Erie since 1900, practically all of which were concerned with the obtaining of additional depths for navigation purposes and conserving water for power and gave no consideration to the increased damage to shore property and shore installations by erosion and inundation aggravated by higher lake levels. The prohibiting factor in implementing any of the suggested regulation studies on Lake Erie has been the great cost involved.

Your Committee was informed in its interview at Chicago with the Division Engineer of the United States Corps of Engineers, that as a result of the recent investigations made by this Corps, it was being recommended to the United States Government that a comprehensive study be authorized to determine the feasibility of a plan of regulation that will best serve the interests of all water users and to determine the advisability of adopting local protection flood control projects for areas subject to flooding from the fluctuations of the levels of the lakes.

8. <u>Effect of the Proposed St. Lawrence Power Developments on the Levels of Lake Ontario</u>

Although the terms of reference to the Committee do not specifically require it to consider the effects on lake levels of proposed control schemes but only to report on present methods of control, nevertheless, since the plans for power development on the International Rapids Section of the St. Lawrence River are inextricably woven with the levels of Lake Ontario, the Committee was of the unanimous opinion that it

should study the proposed method of regulation in the light of its effect on lakeshore erosion and inundation.

On October 29, 1952, the International Joint Commission granted an order of approval in the matter of the applications of the Government of Canada and the Government of the United States of America for the construction of certain works for development of power in the International Rapids Section of the St. Lawrence River. Amongst other conditions this order of approval is subject to those enumerated below, namely:-

(1) All interests on either side of the International Boundary which are injured by reason of the construction, maintenance and operation of the works shall be given suitable and adequate protection and indemnity in accordance with the laws in Canada and the Constitution and laws in the United States respectively and in accordance with the requirements of the Boundary Waters Treaty of 1909.

(2) The works shall be so designed, constructed, maintained and operated as to safeguard so far as possible, the rights of all interests affected by the levels of the St. Lawrence River upstream from the Iroquois regulatory structure and by the levels of Lake Ontario and the lower Niagara River; and any change in levels resulting from the works which injuriously affects such rights shall be subject to the requirements of paragraph (1) above relating to protection and indemnification.

(3) An International St. Lawrence River Board of Control consisting of an equal number of representatives of Canada and of the United States shall be established by the International Joint Commission. The duties of this Board of Control shall be to give effect to the instructions of the Commission. Upon completion of the works the duties of the Board of Control shall be to ensure that the provisions of this order of approval relating to water levels and the regulation of the discharge

from Lake Ontario and the flow through the International Rapids Section as set out in this order are complied with, and the Hydro Electric Power Commission of Ontario and the entity designated by the Government of the United States shall duly observe any direction given them by the Board of Control for the purpose of ensuring such compliance.

(4) Upon the completion of the works, the discharge of water from Lake Ontario and the flow of water through the International Rapids Section shall be regulated to meet the requirements of paragraph (1) above and shall be regulated in accordance with Method of Regulation No. 5 as prepared by the Department of Transport of the Government of Canada, dated September, 1940, and shall be based on the rule curves forming part of that Method of Regulation.

(5) The regulatory works will be operated initially for a test period up to ten years in order to carry out experiments for the purpose of determining whether it is advisable to increase the forebay water level at the power houses to a maximum elevation exceeding 238 feet. At the end of this test period the International Joint Commission will make such recommendations to the two Governments with respect to a permanent forebay water level or it may recommend an extension of the test period.

Mr. G. A. Lindsay, of the Dominion Department of Transport, author of Method of Regulation No. 5, stated that an ideal method must meet the following requirements:

(a) Maintain the fluctuations of the levels of Lake Ontario within the levels that would have resulted in the past, assuming a continuous diversion of 3,200 cubic feet per second at Chicago and present outlet conditions.

(b) Maintain without impairment, the low water levels of Montreal Harbour.

(c) Maintain low flows during the winter period December 15 to March 31, in order that the difficulties of winter power operation are not aggravated.

(d) Maintain flows during the first half of April no greater than would naturally occur, in order to avoid the danger of aggravating the Spring rise in levels during the break-up of the ice below Montreal.

(e) Avoid any material increase in the amount and duration of the high discharges during May, in order not to aggravate high water levels in Lake St. Louis during the times of high flow in the Ottawa River.

(f) Maintain the monthly mean discharges within the limits that existed in nature.

(g) Retard the natural excess outflow during the early summer months, in order to raise the ordinary levels of Lake Ontario.

(h) Secure the maximum dependable flow throughout the year for power operation.

Of all the methods of regulation studied in an attempt to meet all of the above requirements, Mr. Lindsay stated that Method No. 5 appeared to be the best.

During the summer of 1952, the governments of Canada and the United States of America requested the International Joint Commission to study all factors affecting the levels of Lake Ontario, the detailed terms of reference being as follows:

"In order to determine, having regard to all other interests, whether measures can be taken to regulate the level of Lake Ontario for the benefit of property owners on the shores of the lake in the United States and Canada so as to reduce the extremes of stage which have been experienced, the governments of the United States and Canada have agreed to refer the matter to the International Joint Commission for investigation and report pursuant to Article IX of the Treaty relating to boundary waters between the United States and Canada, signed January 11, 1909.

"It is desired that the Commission study the various factors which affect the fluctuations of water level on Lake Ontario, including the construction in the St. Lawrence River known as 'Gut Dam', and any diversion of water into or out of the Great Lakes basin, and shall determine whether in its judgment action can be taken by either or both Governments to bring about a more beneficial range of stage, having regard to the proposed plan for improvement for navigation and power of the International Rapids Section of the St. Lawrence River and the proposed method of regulation of the levels of Lake Ontario which is an essential feature of that plan.

"As a result of its studies under this Reference, it is desired that the Commission shall determine whether, in its judgment, changes in regard to existing works or other measures would be practicable and in the public interest from the points of view of the two governments, having in mind the order of precedence to be observed in the uses of boundary waters as provided in Article VIII of the Boundary Waters Treaty of 1909.

"In the event that the Commission should find that changes in existing works or that other measures would be feasible and desirable, it should indicate how the interests on either side of the boundary would be benefited or adversely affected thereby. The Commission should estimate the cost of such changes in existing works or of such other measures, including indemnification for damage to public and private property arising therefrom and the cost of any remedial works that may be found to be necessary. With due regard to the final paragraph of this reference and to the arrangements presently being proposed for the development of power in the International Rapids Section of the St. Lawrence River, the Commission should indicate how the cost of any measures and the amounts of any resulting damage should be apportioned between the interests involved.

"In the conduct of its investigation and otherwise in the performance of its duties under this Reference, the Commission may utilize the services of engineers and other specially qualified personnel of the technical agencies of Canada and the United States and will as far as possible make use of information and technical data heretofore acquired by such technical agencies or which may become available during the course of the investigation thus avoiding duplication of effort and unnecessary expense.

"It is the desire of both governments that consideration of this Reference shall not delay action by the Commission with respect to applications submitted to the Commission concerning the development of power in the International Rapids Section of the St. Lawrence River."

The International Joint Commission has been working to this end and directing its efforts to obtain the best system of regulation of the levels of Lake Ontario for all users of this water and for those having riparian rights on Lake Ontario and the St. Lawrence River.

In years past, and certainly in the years from 1862 to the present time during which records have been kept, it is quite apparent that in a state of nature there have been wide variations of lake and river levels. It follows if conditions are left as they are now that these variations will continue. With controlled structures at Iroquois and the betterment of river bed and other conditions from thence to the sea, there is no reason why means of control of the lake level cannot be very effectively established. It is intended that the control dam at Iroquois, in conjunction with the excavations in the Galop rapids, would have a discharge capacity greatly in excess of the present river channel. The extensively improved

river channel from thence to the lower part of the river, together with the facilities planned at the Long Sault dam and at the powerhouse, would similarly produce a discharge capacity in this region very much in excess of the highest flow experienced in the past. These increased discharge capacities will permit the discharge of waters more readily at times of high level and thus bring effectively into control the levels of Lake Ontario, which controls do not exist at the present time and have not existed in the past when riparian owners have suffered from the effects of both high water and low water.

5

JURISDICTIONAL ASPECTS OF SHORELINE PROTECTION

1. Riparian Rights and Legal Descriptions of Property Facing Upon Navigable Waters

A riparian proprietor is an owner whose land runs to the water and is bounded by it. If he is able to show that his land is washed by the water, he is entitled at all times to access to the water adjoining his land. If originally his lands were not bounded by a navigable water then he does not become a riparian owner when, by erosion, the soil originally lying between his lands and the waters has been washed away. A riparian owner is entitled to any accretion to his land. Accretion in this respect means a slow and gradual build-up from the action of the water in the ordinary course of the operations of nature and does not include land recovered by reclamation works, nor does it include some unusual or unnatural action by which a quantity of soil is suddenly swept from the land of one man and deposited upon or annexed to the land of another. Land built up by groynes has been held to be an accretion.

If one of the boundaries of the land is the water of a navigable lake or river, and if part of this land is worn away by erosion so that the waters of the lake or river cover it, the land so covered by water becomes the property of the Crown during the time it is submerged. Where one of the boundaries of the land is the high or low water mark, this boundary may change from time to time, and the owner always has access to the water.

At common law the foreshore, that is the land lying between the high and low water marks, is in most cases,

the property of the Crown, but because early patents in Ontario described the boundaries of lands bordering waters in a variety of ways, this _prima facie_ rule cannot be accepted as of any general application in this Province. As a matter of record eighteen phrases have been used in patents at different times in Ontario describing the boundaries of lands bordering on water; these are:

"along the bank"
"along the shore"
"along the water's edge"
"along the front"
"along the front on the bank"
"along the waters of the lake"
"along the shore of the water"
"along the front of the bay"
"along the edge of the waters"
"along the edge of the water thereof"
"along the bank of the lake"
"along the lake"
"along the shore of the lake"
"down the river"
"along the top of the bank"
"along the high-water mark"
"along the low-water mark"
"round the island on the shore at low-water mark"

It would seem that in some cases the foreshore is included in the grants. In other cases the grants do not include the foreshore, and, in many cases, the words would have to receive judicial interpretation before their meanings would be clear.

In 1940 an amendment to The Bed of Navigable Waters Act was enacted by the Legislature. The purpose of the amendment was to make uniform the interpretation of the many various wordings in Crown grants of land bordering on a navigable body of water, and the amendment purported to fix the boundary in every such grant as high-water mark, regardless of the wording in the grant. After a few years it became apparent that it was impracticable to administer the 1940 amendment, and it was repealed in 1951.

2. <u>Policy of the Government of the United States on Shore Protection</u>

In 1930 Congress enacted Public Law 520 which authorized and directed the Chief of Engineers, United States

Army, under the direction of the Secretary of the Army, to cause investigations and studies to be made in co-operation with the appropriate agencies of various coastal and Great Lakes States with a view to devising effective means of preventing "erosion of the shores of coastal and lake waters by waves and currents". Under this Act no money may be expended in any State unless that State or its agencies co-operated in the costs of the investigations. The amount of co-operation was subsequently established at fifty per cent. This Act also established a Beach Erosion Board consisting of seven members, four of whom must be officers of the United States Corps of Engineers and three engineers to be selected by the Chief of Engineers. The scope of the Board's activities was at first restricted largely to the furnishing of technical assistance in the conduct of studies and of reviewing reports of investigations.

Federal participation was broadened by 1945 legislation, Public Law 166, assigning to the Beach Erosion Board the duty of making general investigations and research in shore erosion on long stretches of shoreline and determining the most suitable methods for the "protection, restoration and development of beaches". Also added was the duty of publishing technical information relating to the problem of beach erosion and its control. The costs of these general investigations are borne wholly by the Federal Government and require no local co-operation.

In 1946 Congress enacted legislation, Public Law 727, directed specifically toward Federal participation in the construction of works for the protection of publicly owned shores. This enactment stated that:

> "it is hereby declared to be the policy of the United States to assist in the construction but not the maintenance of works for the improvement and protection against erosion by waves and currents of the shores of the United States that are owned by States, municipalities, or other political subdivisions, provided that the Federal contribution toward the construction of protective works shall not in any case exceed one-third of the total cost".

The Committee was advised by the United States Corps of Engineers that this law does not restrict the scope of study provided by the Act of 1930 but merely provides for federal participation in the cost of protection of publicly owned property. The Federal Government can prepare through its Corps of Engineers, a plan for the protection and improvement of a section of shore as heretofore but the Board must now study the economic justification of improvement and protection of the publicly owned portion of the shore and determine the amount of federal participation to recommend. To be economically justified the costs are amortized and the carrying charges have to be offset by prospective benefits. A general thumb-rule used by the Great Lakes Division of the United States Corps of Engineers in computing prospective benefits to public owned property is on the basis of 25 cents per person using the beach and 75 square feet per person.

The following describes the steps taken in a local - federal beach erosion project.

An application for study is filed with the District Engineer of the United States Corps of Engineers by the municipality or state government that owns lakeshore land which has an erosion problem. The District Engineer goes over the matter with the applicant and after consultation, the terms of the study are agreed upon and the state or municipality must contribute half the cost either in money or in services.

The District Engineer then executes the study and makes a report. He has to report on the advisability of adopting the project, the public interest involved and the Federal Government's share, which need not necessarily be the full third provided by law. Finally, the District Engineer must specifically state that local interests must supply all the funds not contributed by the Federal Government and that some responsible local agency must assume responsibility for maintenance for providing all lands rights-of-way, and easements required and for claims for damages.

The District Engineer's report is submitted to the Beach Erosion Board who have two things to do. First they act as a court of appeal for people who feel injured by the report and second, they have to check the report for engineering and economic errors. The Beach Erosion Board pass this report with their observations to the Chief of Engineers, United States Army, and then to Congress.

If Congress approves the document the provision of the Federal share will then become a matter of securing the requisite appropriations. Before construction is started, the Chief of Engineers approves of the detailed plans and specifications and makes arrangements for the prosecution of the work.

In the case of inundation from high lake levels the laws are the same as those governing flood protection from rivers. Congress can authorize a flood protection project for any given area and the amount contributed by Congress can be anything up to 100 per cent depending on the division of public and private interests and the degree of national emergency. In the case of inundation the Federal Government can assist on private properties.

3. Policies of Some of the States Fronting the Great Lakes on Shore Protection

(a) Indiana

The State of Indiana has 45 miles of shoreline on Lake Michigan. Its statutes* provide for two types of activities in connection with the protection of this shoreline. Firstly, authority is granted municipal governments to charge the cost of shore protection directly to the property owners that are benefited. Secondly, there may be established a Flood Control and Water Resources Commission which is the state agency authorized to co-operate with the federal or municipal governments in shore protection.

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* Burns Indiana Statutes, Chapt. 27, Section 1116 and Chapt. 48, Section 5208

Your Committee was informed that no state monies have been spent on the protection of private lands fronting Lake Michigan.

(b) Michigan

The State of Michigan has approximately 1875 miles of shoreline on the Great Lakes. A State Water Resources Commission is "the designated State agency to co-operate and negotiate with other governments, governmental units and agencies thereof" on matters of beach erosion control and it is "authorized to take such steps as may be necessary to take advantage of any act of Congress heretofore or hereinafter enacted which may be of assistance in carrying out the purposes of this Act".

Your Committee was informed that while "co-operation" might be construed to imply active participation in the actual financing or construction of beach erosion control measures sponsored by other governmental units, budgetary limitations have prevented the State from doing more than supplying information on methods of erosion control to local government units.

The only provision for constructing protective works for beach erosion control is found in permissible public improvements for townships to be paid for by assessment of benefited property.

(c) Ohio

The State of Ohio has 312 miles of shoreline on the Great Lakes. This State has laws which permit State participation with municipal councils to the extent of two thirds of the first cost of works for the protection of public owned property. The maintenance of the works is the responsibility of the municipality that owns the shore property. Within its Department of Natural Resources there is a Division of Shore Erosion which conducts research work in beach protection matters and supervises the administration of the State's participation in constructing protective works.

(d) New York

The State of New York has 375 miles of shoreline on the Great Lakes. The construction of public works for the arresting of erosion in which the State participates is confined only to their lands along the Atlantic Coast. In this case, the State may contribute up to 50 per cent of the cost of such works on municipal public beaches which thereafter are maintained at the expense of the municipality. At present there is no law which permits State aid to municipalities on the Great Lakes for the purpose of shore protection nor is State aid available to private riparian owners on the Great Lakes or the Atlantic coast for such protection.

Your Committee wishes to point out that although each of the States bordering the Great Lakes has a very much less shoreline frontage than has Ontario, and that the problems of erosion and inundation are in most cases more acute by reason of the greater density of population and of shoreline development, it is significant that not one of these States has established a policy of spending public money on the construction of protective measures for private lands.

4. Interpretation of the Laws of Canada and of the Province of Ontario in Relation to Shoreline Protection

The British North America Act, construed according to its plain meaning, confers upon the Provinces exclusive power to make laws in relation to matters coming within certain classes of subjects as set forth in Section 92 of the Act. The balance of power is vested in the Government of Canada with the exception of certain concurrent powers in relation to which both the Government of Canada and the Provinces can legislate. In relation to this concurrent power where a conflict arises, legislation of the Government of Canada prevails.

However, it is necessary to point out that the jurisdiction and responsibilities of the respective governments

of Canada and the Provinces are rather flexible and cannot be ascertained by a cursory glance at the bare words of the sections of the British North America Act, for the sections have been variously interpreted from time to time by the Canadian Courts and by the Privy Council in England.

In Canada, there is a double jurisdiction in regard to waterways. The Government of Canada obtains its power in this regard from Sections 91 and 108 of the British North America Act and the Province of Ontario from Sections 92 and 109.

The effect of the Sections above referred to in relation to navigable waters and the land fronting on the same is that the Province owns the bed of all navigable lakes and rivers, including the beds of the Great Lakes to the international boundary excepting:

(1) The beds of all public harbours as they existed at the time of Confederation;

(2) River improvements in existence at the time of Confederation;

(3) Lake improvements in existence at the time of Confederation.

The beds of harbours which were public harbours at the time of Confederation and the river and lake improvements in existence at that time remain vested in the Dominion.

The ownership of Ontario nevertheless is subject to a very real right somewhat in the nature of an easement which is the right of the Government of Canada to control navigation. Thus the Province of Ontario cannot, nor may any citizen or corporation, erect any structure in its own lakes or rivers which would interfere with the exercise of the Government of Canada's prerogative of navigation.

The Public has a right to travel on navigable waters, and whether the waters are "navigable waters" or not is a question of fact to be determined having regard to all

the facts. The test of navigability is the utility of the waters for commercial purposes, and it is not dependent upon the size of boats nor the fact that navigation be continuous. Also the fact of navigability obviously has not been determined for all lakes and rivers in Canada, but where it has not already been done it is determined only when the question of navigability arises.

After Confederation, certain navigation aids also became the property of the Government of Canada, such as canals, public harbours and lighthouses. However, the Government of Canada cannot erect structures which are not for navigation purposes such as those using water for generating electric power. Such use is incidental to the ownership of the bed of the river.

In respect to the development of ports, there are also limits to the Dominion jurisdiction. Thus the foreshore and bed cannot be expropriated without compensation in order to extend a present existing harbour.

5. Zoning for Shore Protection

The effectiveness of zoning laws in controlling the development of lakefront properties is a subject that has been discussed at many of the Committee's hearings. By zoning, the Committee means the restriction of development on sections of lakefront property that are subject to inundation or erosion.

Essentially the problem resolves itself into determining the limit of inundation or shoreline recession which may be expected in any particular area and then prohibiting construction within that zone. The problem of zoning must be given careful study for each individual locality and cannot be treated in a general manner. It involves the consideration of possible land uses and possible loss by erosion or inundation. In some cases, this may justify structures of limited value. The problem of zoning also requires a carefully prepared prediction of future shore recession rates and limits

of flood plains which can only be made from a study of past records.

Determining the limits of land subject to flooding or inundation is not difficult with the records of lake levels that are available, yet in many sections of the Great Lakes shoreline, people have ignored nature's past performances and have built on lands that are naturally subject to inundation. The Committee does not say that because a section of the shoreline was inundated only once or twice in the period of records that is, since 1860, the property should not be developed. Many people may be prepared to risk an investment to build on such a property in view of their desire to live near the water. In the course of the Committee's inspection of seriously affected areas, instances were noted of building actually in progress with the lake lapping at the doorstep. The Statutes of Ontario make no provision whereby those who, in spite of these immutable laws of nature and our records of them, build on unprotected land that is within the zone of the natural ranges of lake levels are entitled to indemnification out of public funds to redeem their poor investment, and this Committee is strongly of the opinion that no such provision should be made.

Determining the limits of a zoning area on land that is subject to lakeshore erosion is by no means simple. With very few exceptions the entire shoreline of the Great Lakes is receding, the rate depending primarily on the physical characteristics of the shore. With a rate of recession as high as seven feet per year, as does occur in some sections of our shoreline, what may be considered safe this year may be very hazardous twenty years from now. It would appear to your Committee that if residential or industrial development is to proceed on lakefront property the cost of such development should include the cost of providing reasonable protection. If the cost of such protection is excessive compared

(Hamilton Spectator)

Determining the limits of land subject to inundation by the Great Lakes is not difficult with 92 years of records of lake levels that are available, yet on many sections of these lakes people have either entirely ignored or were not aware of nature's past performances and have built on unprotected lands that are naturally subject to inundation.

to the value of the developed property it would appear that such property should be zoned with the view to restricting that type of development.

Under The Municipal Act and The Planning Act authority is given to municipalities to zone and regulate the development of all lands within their municipality. They are also empowered by these statutes to prevent development of lakeshore property until adequate protective works have been installed.

Section 390, paragraph (1), section (1), of The Municipal Act provides that municipal councils may pass By-laws prohibiting the use of land within any defined areas in their municipality. Section 3 of paragraph (1) of this Act defines these powers more specifically and provides for prohibiting the erection of buildings for residential or commercial purposes on land of an "unstable character". Areas subject to rapid lakeshore erosion might well be classified as being of an "unstable character". Municipalities have a responsibility and the authority to prohibit or to restrict the development on their lakeshore properties where its long term protection is not economically feasible and where such action is in the public interest.

Section 25 of The Planning Act enables the Minister of Planning and Development to exercise any of the powers conferred upon the councils of municipalities by section 390 of The Municipal Act, on lands not covered by an official plan or not within the scope of a By-law passed under section 390 of The Municipal Act. Your Committee is of the opinion that these powers conferred on the Minister of Planning and Development should be broadened to prohibit or restrict the use of any lands bordering the Great Lakes which is subject to erosion and inundation. Your Committee

therefore recommends:

THAT WHEREVER ON THE SHORELINE OF THE GREAT LAKES IN ONTARIO LAND IS SUBJECT TO SUCH EROSION OR INUNDATION AS IN THE JUDGMENT OF THE MINISTER OF PLANNING AND DEVELOPMENT MAKES IT UNSUITABLE FOR PRIVATE DEVELOPMENT THE MINISTER BE EMPOWERED TO RESTRICT OR PROHIBIT THE USE OF SUCH LAND UNTIL SUITABLE PROTECTIVE WORKS HAVE BEEN INSTALLED.

and

THAT WHEREVER ON THE SHORELINE OF THE GREAT LAKES IN ONTARIO THE USE OF LAND IS RESTRICTED OR PROHIBITED BECAUSE OF THE THREAT OF EROSION OR INUNDATION, THE MUNICIPALITY OR THE VALLEY CONSERVATION AUTHORITY, IF SUCH HAS BEEN ESTABLISHED IN THE AREA IN WHICH SUCH LAND IS SITUATE, BE EMPOWERED TO ACQUIRE THESE LANDS FOR PARK, RECREATION, OR PROTECTIVE PURPOSES, AND THAT POWER BE GIVEN THE MUNICIPALITIES AND AUTHORITIES TO EXPROPRIATE SUCH LANDS AND THAT SUITABLE LEGISLATION BE PROVIDED.

6. Disposition and Acquisition of Public Lands Bordering on Navigable Waters

The Committee considers that the following matters are of sufficient importance to warrant their study by the Ministers of the Departments concerned.

Reference has been made in Chapter Two to the significance of the Great Lakes in providing public recreational sites. In considering this very important use of the Great Lakes and their beaches your Committee has kept in mind the anticipated increase in the population of the Province within the next twenty-five years which makes imperative the preservation and acquisition for public use of adequate lands bordering on the Great Lakes to meet the growing needs of the Province.

Where Crown lands fronting the lakes do exist, it has been the policy of the Government of Ontario, since 1947, to retain two lots in ten for recreational purposes. North of the French River these lots have a frontage of 300 feet, south of the French River, 200 feet. The selection of these lots is made by the field officers of the Department of Lands and Forests and the lots so reserved are the best available for such purposes and are not those that have been left over after the bulk of the land has been patented.

The granting by the Crown, in the past, of land "to the water's edge" is a situation found mainly along the shores of Lake Ontario, Lake Erie, Lake St. Clair, Lake Huron, Lake Simcoe, the Detroit River, St. Lawrence River, and part of the Ottawa River. In 1851 the 1,000-acre block system of survey of Crown lands was adopted which introduced the establishment of a one-chain allowance for road along the shores of lakes and navigable rivers. This system was used in laying out townships extending from Georgian Bay to the Ottawa River. Some 200 townships of this type were surveyed. In all subsequent surveys (with a few exceptions) an allowance for road was made along the banks of lakes and navigable rivers. This allowance for road is laid down immediately above and abutting the high-water mark, and Crown grants of land bordering on navigable waters where the allowance for road is made are bounded by this allowance for road; in other words, the boundary is in such cases 66 feet from the high-water mark.

It is well known that many owners of such land, unwittingly or with knowledge that they have no title, have erected structures and made improvements on the allowance for road fronting their lands. It is a situation difficult to control, but those trespassing on the allowance for road cannot thereby acquire a prescriptive right to such land by length of possession, except those persons who may have

acquired any right before June 13, 1922. (The Limitations Act, R.S.O. 1950, chapter 207, section 16.)

Such allowances for road are by virtue of The Municipal Act, (section 427) vested in the municipality. During the time before there is municipal organization, the allowances for roads are vested in the Crown. By virtue of The Municipal Act (section 426) allowances for roads made by the Crown surveyors are deemed to be highways. The municipal corporation having jurisdiction is empowered by The Municipal Act (section 469) to stop up and to lease or sell the soil of a highway or part of the highway, and in the case of an allowance for road along or leading to the bank of any river or stream, or on the shore of any lake or other water, the approval of the Lieutenant-Governor-in-Council must be obtained.

The disposition by the municipality of such allowances after their stoppage has been authorized does not require further approval. The municipality and all Departments of Government concerned should satisfy themselves these allowances for roads are not required for public purposes before disposition is considered.

In the case of unorganized territory the Lieutenant-Governor-in-Council is empowered to stop up and lease or sell any highway or part of a highway reserved in the original survey. (The Municipal Act, section 490.)

Although there may not appear to be an immediate need in unsettled areas to retain in the Crown such allowances for roads, the general policy should take into full consideration the possible need of the allowances for roads in the future development and settlement of those areas. In view of the foregoing your Committee is of the opinion that:

1. No disposition should be made of Crown land bordering on water and distant 66 feet measured at right angles from the high-water mark until due consideration has been given by all departments of the Public Service of Ontario and The Hydro-Electric Power Commission of

Ontario and until a public hearing has been held either by the County Judge of the county or district in which the lands are situate or by The Ontario Municipal Board and notice of the proposed hearing shall be published once a week for four successive weeks in a local newspaper published in the county or district and in the Ontario Gazette, and that the present policy of the Government of setting apart adequate and desirable areas for public use should be continued and that such areas should be suitably marked.

2. All allowances for roads reserved in an original survey along or leading to the bank of any river or stream, or the shore of any lake or other water in unorganized territory should not be disposed of to other than public bodies until a public hearing has been held either by the County Judge of the county or district in which the lands are situate or by The Ontario Municipal Board, upon notice, at which time the County Judge or The Municipal Board shall be satisfied upon representations made by persons interested in relation to the said disposition, including all departments of the Public Service of Ontario, that the allowance for the said road is not, or is not likely to be, required for public purposes.

3. Every By-law passed by a municipality for stopping up and selling any part of a road allowance reserved in the original survey along or leading to the bank of any river or stream or on the shore of any lake or other water shall not take effect until it has been duly considered by all departments of the Public Service of Ontario and The Hydro-Electric Power Commission of Ontario and until a public hearing has been held either by the County Judge of the county or district in which the lands are situate or by The Ontario Municipal Board

and notice of the proposed hearing shall be published once a week for four successive weeks in a local newspaper published in the county or district and in the Ontario Gazette.

Where land is open for staking under The Mining Act the reservation to the Crown of surface rights of lands bordering the lakes does not exceed 200 feet from the water's edge. It is the opinion of your Committee that this reservation should be extended to a depth of 400 feet from high-water mark, in respect of those waters agreed upon from time to time by the Minister of Mines and Minister of Lands and Forests, wherein, in their opinion, it is in the public interest so to do.

Considering that more than one-half of the Province's population of four and a half million people live within twenty-five miles of the shore of Lakes Ontario, Erie and Huron, the shores and beaches of these lakes ought to be available for intense use by the public. Such is not the case.

It is the opinion of your Committee that more consideration should be given to the acquiring of beaches and parkland on the shores of the Great Lakes for the use of the public through the initiative of Conservation Authorities, municipalities and semi-public bodies.

6

THE NATURE OF PROVINCIAL PARTICIPATION

The employment of adequate shore protective measures depends on the following factors:-

(i) The relation of the cost of protection to the enhanced value to the riparian and adjoining lands.

(ii) The degree to which it is in the public interest to protect the shores of the Great Lakes.

Inasmuch as erosion and inundation on the Ontario shoreline of the Great Lakes has in some years caused widespread and serious property damage and loss this Committee is of the opinion that the Provincial Government should have an interest in its abatement. The degree of this interest is contingent on whether the land is of a private or public nature, and is tempered by the fact that Ontario has approximately 3,000 miles of Great Lakes shoreline on the mainland alone. In formulating recommendations the Committee has studied the policies of the Great Lakes States. Each of these States has but a fraction of the length of Ontario's shoreline, and yet no State has spent public money on the installation of lakeshore protective works on private lands.

This report has emphasized the urgent need for fundamental data concerning engineering aspects of protective measures, and for knowledge of lake currents and beach forming processes.

The Committee is of the opinion that participation by the Provincial Government in shore protection should initially be limited to conducting studies, amassing information and publishing data on all aspects of shore protection,

and it is recommended:

THAT FOR THE PURPOSE OF OBTAINING INFORMATION REGARDING THE EFFECTIVENESS OF SHORE PROTECTIVE STRUCTURES ALL PERSONS WHO ARE DESIROUS OF CONSTRUCTING PROTECTIVE WORKS ALONG THE SHORES OF THE GREAT LAKES FILE WRITTEN PLANS WITH THE MINISTER OF PLANNING AND DEVELOPMENT OF SUCH WORKS AND THAT NO PROTECTIVE WORKS BE UNDERTAKEN UNTIL SUCH PLANS HAVE BEEN SO FILED.

and

THAT OWING TO THE LACK OF PUBLISHED DATA ON THE EFFECTIVENESS OF VARIOUS TYPES OF BEACH PROTECTIVE MEASURES AND THE CONDITIONS UNDER WHICH EACH IS MOST EFFICIENT, THE DEPARTMENT OF PLANNING AND DEVELOPMENT CORRELATE AND PUBLISH ALL PERTINENT AVAILABLE INFORMATION.

Having in mind the desirability of protecting lakefront property that has a reasonably intense public use, the Committee recommends:

THAT WHERE A MUNICIPALITY OR GROUP OF MUNICIPALITIES OWN LANDS ON THE SHORES OF THE GREAT LAKES AND CONNECTING WATERWAYS WHICH ARE USED BY THE PUBLIC AND ARE PREPARED TO UNDERTAKE PART OF THE COST OF PROTECTING THESE LANDS FROM EROSION AND INUNDATION, THE PROVINCIAL GOVERNMENT MAY GRANT FINANCIAL ASSISTANCE FOR THE CONSTRUCTION OF APPROVED REMEDIAL MEASURES.

In connection with the construction of beach protective measures there is a great need in the Province to have information on the effectiveness of various types of protective structures under different shoreline and lake current conditions. The Committee feels that this need can be most effectively met by constructing various types of protective works on Provincial Government properties at selected points on

the Great Lakes where erosion and inundation is a problem and it is therefore recommended:

THAT FOR THE PURPOSE OF DEMONSTRATION AND EXPERIMENTATION PROTECTIVE WORKS BE CONSTRUCTED ON PROVINCIAL GOVERNMENT PROPERTIES AT SELECTED POINTS ON THE GREAT LAKES AND CONNECTING WATER-WAYS WHERE EROSION AND INUNDATION IS A PROBLEM.

The regional nature of shore protection problems generally requires that protective measures for one particular property must be considered in relation to its effects on adjoining properties. The Committee has witnessed cases where the protection of one property has been rendered ineffective by the lack of protection on the adjoining properties. Cases have also been noted where the protection of one property has accelerated the erosion of adjoining properties. In view of the regional requirements of effective shore protective measures it is therefore recommended:

THAT WHERE ON THE SHORES OF THE GREAT LAKES A GROUP OF CONTIGUOUS, PRIVATELY OWNED PROPERTIES ARE CONSIDERED TO BE AN OPERATING UNIT BY THE MINISTER OF PLANNING AND DEVELOPMENT, AND WHERE THE MAJORITY OF SUCH LANDOWNERS PETITION THE MUNICIPALITY FOR ASSISTANCE IN PLANNING REMEDIAL MEASURES, THE MINISTER OF PLANNING AND DEVELOPMENT ON THE APPLICATION AND RECOMMENDATION OF THE MUNICIPALITY MAY MAKE A SURVEY AND PREPARE A PLAN AND REPORT INDICATING THE TYPE OF PROTECTION REQUIRED AND THE APPROXIMATE COST INVOLVED.

PART TWO

LAKESHORE PROTECTIVE MEASURES

PART TWO

7

BASIC PRINCIPLES OF PROTECTIVE MEASURES

The science of shore and beach protection as we know it today is a comparatively new concept in engineering. Although shore protection work has been carried out the world over for centuries the results, in general, have not been satisfactory. This fact is well attested by the wreckage of such works that litter our shores today and by the knowledge of the thousands of dollars that have been spent on these structures without permanent results. That such conditions exist appears to be due to many factors. Outstanding among these is the apparent failure to recognize: the magnitude of the destructive forces at work, the need of comprehensive studies covering a large section of shoreline at one time, and the failure to provide for unforeseen conditions that might reasonably be expected to occur. Moreover, shore protective works are costly, and in many instances, the size and type of structure were limited by the funds available.

In the past, many of the structures were designed in accordance with inadequate ideas of the times or were simply copies of other structures which had proved reasonably effective elsewhere. Much of the work was done on a "trial-and-error" basis. Sometimes such works were successful, but more often they were of no value and have been the means of accelerating the erosion of adjacent properties.

As a result of these numerous failures the general public, and the engineering profession in particular, have become aware of the inadequacy of the design methods in common use and the serious lack of knowledge of the destructive forces which bring about these failures. The importance of

thorough preliminary studies covering whole segments of the shoreline rather than small isolated areas has been realized and research on the whole matter of beach erosion and protection has been undertaken by many engineering groups and colleges. Although much remains to be done in the way of determining data on shore processes and developing reliable design methods, valuable information is steadily being accumulated and made available in technical literature.

In discussing the basic principles of shore protection it is necessary to take full cognizance of the forces to be dealt with and that each locality is a law unto itself and must be considered individually. It is not possible to design any one type of protective measure to satisfy all the trouble areas, nor is there any simple rule for determining the extent of the preliminary studies necessary in any particular case. Generally the extent of these studies is determined by the magnitude of the project, but experience has shown that a thorough study is required in all cases and that savings are seldom realized by any curtailment in this phase of the work. Since each locality presents a different problem, detailed and accurate information on the local conditions and the purpose for which the area is to be developed must be obtained in order to provide a satisfactory solution to the problem and produce the greatest benefit per dollar spent.

The preliminary studies would involve the investigation of all the natural forces acting on the shoreline and the shore processes resulting therefrom and would include such essential factors as:

1. Past history of the area
2. Shore and foundation characteristics
3. Lake levels
4. Currents
5. Littoral drift
6. Wave forces
7. The Effects of wind and ice
8. Degree of protection required
9. Improvement desired

An illustration and definitions of terms used in these studies are shown on Plate No. 8.

It has been pointed out above that each locality presents its own set of characteristics and therefore local conditions will, to a large degree, dictate the extent of the study and information required. Studies on a flat sandy beach area, for instance, would not necessarily follow the same pattern as one for a high bluff area. Nor would a sparsely populated undeveloped area warrant such a detailed survey as a more densely populated and highly developed area such as we have in some of the larger municipalities along the lakeshore. However, in all cases, the study must be sufficient to ensure that the subsequent work will be properly designed to withstand the destructive elements and to achieve the desired result.

1. Past History of the Area

A study of the past history of an area is most useful in leading to an understanding of the causes of the shore changes that are taking place; the rate at which they are progressing, and what might be expected to occur if they are allowed to continue. Among the principal items to be investigated in considering the past history of an area are geolcgy, shoreline changes, offshore changes, storm effects and protective measures used and their effectiveness.

The geology of the area should be reviewed to determine the causes of the type of shore encountered, the source and character of the local beach materials and the general geological structure of the vicinity. It may not be necessary to employ a geologist in the field but at least the available geological maps and reports of the area should be consulted. However, where extensive and costly works are contemplated it would be highly advisable to have a detailed geological investigation made of the area in question.

The history of the shoreline changes may be obtained from a comparison of the available maps of the area. The value of such a study generally increases with the length of time covered but even short periods of record are invaluable

in a study of this nature and should not be overlooked. If sufficient reliable maps and other survey data are available a good picture of the progressive changes that have occurred in the past may be obtained.

Offshore changes may be traced in a similar manner. Unfortunately except for the older and more important harbour areas hydrographic maps are practically non-existant and in most cases it would be necessary to rely upon the observations of local residents for such information. Where sufficient data is available to indicate the long-term trend of offshore depths then the engineer may take into account the probable changes that may be reasonably expected to occur and modify his design accordingly. Should the trend reveal a progressive deepening of the offshore area then it is evident that more severe wave action may be expected at this point while on the other hand the reverse would indicate a probable lessening of the destructive wave action.

In addition to the above a knowledge of the general effects of severe storms has been found of value. This information may be obtained from local residents, newspapers, photographs and other records. In view of the danger of exaggeration in eye-witness accounts this evidence should not be relied upon too heavily unless it has been verified by other individuals. Photographs and authentic maps showing conditions before and after a storm are the most reliable sources of information. But these would not indicate the wave heights, direction of approach of the storm waves nor the sequence of events during the storm action and thus it would be necessary to rely on the local descriptions to this extent.

Where shore protective works have been installed a complete and accurate record covering location, type, date of construction, present condition, probable life and the effect on the beach should be made. If possible, copies of the original plans and specifications should also be obtained.

Usually the set of plans will contain a map of the shore area at the time of construction and if so, an accurate picture of the changes within the area may be revealed by a comparison with more recently prepared maps.

2. <u>Shore and Foundation Characteristics</u>

In designing any shore protective structure it is important to know the topographical features of the area and the physical characteristics of the surface and sub-surface materials. Topography, in a large measure, dictates the first choice of type of structure. For extensive and detailed studies sufficient survey data should be obtained to show the character of the country some distance inland and lakeward to at least the 6 foot depth, or more if comparatively rapid changes in the offshore area are suspected. The beach and offshore area should be surveyed in sufficient detail to permit the plotting of profiles extending from the backshore down across the beach and out into the lake to the desired depth. These should be at not more than 100 foot intervals along the entire length of shoreline under study. Such profiles would indicate the height of the bluffs or dunes, the general shape and slope of the beach and the offshore bottom and the location of the high and low water lines. Careful notes should be made of any structures along the shoreline as to their location, height, length and spacing. Also careful observations should be made of their effect on the shoreline. Aerial photographs are useful for this phase of the work for showing the general character of the shore, the extent of developed areas and building.

Mechanical analysis of the surface material are made to determine composition, the grain sizes, specific gravity, porosity, shell content and degree of wetness since this factor greatly affects the physical properties of the material. Also these analyses will aid in tracing the source of the materials and thus give some indication of the littoral drift and will indicate whether or not they are suitable for

use in the proposed work. In many cases beach materials form an ideal aggregate for concrete and substantial savings may often be made by using the natural materials on hand.

Sub-surface conditions present one of the most important features to be investigated. Information as to the nature and depth of the unconsolidated material and the possible existence of ledge rock must be obtained before continuing with the design of any proposed work. Of the methods available for obtaining this information the open test pit method is probably the simplest and best where the surface mantle is relatively shallow and dry. Sounding rods may be used in light shallow soils to determine the depth of unconsolidated material and are often satisfactory for small projects. Boring is the most reliable but the most expensive method of determining the nature, extent and structure of the sub-surface materials. By this method soil samples and cores may be obtained which will give a continuous, accurate and permanent record of the subsurface structure. Geophysical methods such as electrical resistivity or seismic methods, are often used for preliminary surveys of large areas where the geological structure is not too complex and time is a factor.

Probings should be spaced at critical points along selected profiled sections and should extend to bedrock or at least 20 feet below the mean low water line.

3. Lake Levels

Although there are no tides to speak of on the Great Lakes there are irregular variations brought about by such natural factors as precipitation, evaporation, winds and barometric pressures. Lake levels are usually low during the winter months and high during the summer months but unusual climatic conditions may upset this general trend. In addition to the seasonal variations there are long-time cycles of higher and lower waters with the maximum difference between extremes

ranging as much as 6 feet or more. It is apparent that variations of this amount must be considered in designing protective works. The Canadian Hydrographic Service has kept accurate records of the water levels in all the Lakes since 1860 and from these records valuable information such as: the minimum and maximum water levels with dates; the range of annual variations; and the occurrence and duration of major periods of high and low water stages may be obtained.

From the records it is apparent that there is no regularity between these long-time cycles of high and low water stages and therefore it would be difficult to predict future trends. However, from a study of these records in conjunction with precipitation records for the drainage area it will be noted that, in general, periods of high water follow periods of high precipitation and periods of low precipitation are followed by low levels. Thus, by establishing the "wetness factor" of the Great Lakes drainage area a fair short time prediction may be made regarding the trend in lake levels. But, here again, unusual climatic conditions may upset such predictions.

The average seasonal pattern of variations shows low levels in the winter and high levels in the summer but lows and highs on each of the lakes have occurred in almost every month of the winter and summer because of abnormal conditions. Average monthly mean water level* for each of the lakes for the period 1860 - 1952 are:

Lake Superior	602.29	Lake Erie	572.34
Lake Huron	580.57	Lake Ontario	245.89
Lake St. Clair	574.77†		

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* Elevation in feet above mean sea level datum adjusted to the United States Lake Survey datum, 1903.

† Level reported by United States Lake Survey Office based on their records 1898 - 1951.

In addition to the long period and seasonal variations the lakes are subject to oscillations of irregular duration and amount. These variations range from a few inches to several feet and may extend over a few minutes or several days. At times the lake levels are affected by winds which raise the water level on the lee shore and lower it on the weather shore. The maximum of these rises recorded on the lakes together with their probable frequency are indicated below.

TABLE NO. 15

FREQUENCY OF MAXIMUM SHORT PERIOD FLUCTUATIONS*

Lake	Location	Max. Rise (feet)	Probable Frequency Once in - (Years)
Superior	Westerly end	2.1	10.0
	Easterly end	1.3	8.5
Huron	Northerly end	1.7	13.5
	Southerly end	2.5	9.5
Erie	Westerly end	4.5	10.0
	Easterly end	8.4	48.3
Ontario	Westerly end	2.9	15.8
	Easterly end	2.1	3.5

Lesser rises of the order of 1 to 1.5 feet occur more frequently on the lakes and Lake Erie experiences rises of 2 to 3 feet several times a year.

The principal effect of changing water levels is its control of the design, layout and construction of shore protective works. During high stages such works would be subject to higher storm waves and thus greater destructive forces. During low water stages the structures may be well beyond the reach of all but the greatest storm waves while on the other hand the lowering of the water may expose other structures to the maximum wave forces and therefore the full

* From data prepared by the United States Lake Survey.

range of water levels must be provided for in the design. A knowledge of the low water levels is important where timber is used for the substructure. Timbers kept submerged will last indefinitely in fresh water but are comparatively short lived when subject to alternate wetting and drying. Also the water level obtaining at the time of construction will affect the cost of the work. The cost usually increases proportionately with an increase in water level due to the added risk of storm damage during construction.

4. Currents

The waters of the Great Lakes are continually being shifted about by currents of various kinds of which the main ones are: (1) body currents produced by the flow of water from the inlet to the outlet; (2) littoral currents set up by waves striking the shore obliquely and (3) undertow caused by the escape of water piled up against the shore by waves. Of these three the littoral currents are the most active and are the ones which are more directly concerned in studies for shore protection measures. Normally body currents in such large bodies of waters as the Great Lakes are not swift enough to produce any appreciable material movement. Strong undertows moving lakeward down a shelving bottom carry material away from shore and deposit it in places too deep to be affected by subsequent motion of the water. Individual storms have brought about serious erosion in this manner.

The littoral currents are responsible for the movement of beach forming material along the beaches and for the scouring and undermining of shoreline structures. Therefore it is apparent that a knowledge of these currents is important prior to designing any shore protective scheme. The important factors to be determined in this regard are the velocities and prevailing directions of the shore currents.

Current velocities may be measured by the travel of floats, clouds of coloured water or liquids, current meters or a combination of these methods. The use of coloured water is preferable when wave action will permit. Surface floats are moved only by the top filament of water and are usually influenced to a large extent by winds but this difficulty is easily overcome by the use of properly designed sub-surface floats. These floats consist of a small wooden staff to the bottom of which are attached four metal fins at right angles to each other. The staff is fitted through a small wooden block so that it will float upright and has a small flag attached to the top in order that it may readily be followed. The staffs are of various lengths to permit current measurements in any depth of water or at any level in a given depth. The current velocity is determined by timing the floats over a known distance.

Waves approaching a beach obliquely set up a swift current just outside the plunge point. In their uprush oblique waves make a long sweep along the foreshore at velocities high enough to cause the rapid movement of sand and gravel. These velocities may be conveniently measured by coloured liquids such as analine dye, permanganate of potash or washing bluing which can be followed 100 feet or more before disappearing. During more severe storms information on currents may be obtained by throwing weighted blocks of wood or partly filled bottles out from the shore and timing their longshore movement. None of the above methods give the true water velocities since they only indicate the resultant lateral movement and do not take into account the shoreward and lakeward components. Thus, while the current velocities may appear to be comparatively low the actual water velocities may well be sufficient to move considerable volumes of beach material.

The current directions will also be indicated by the velocity tests but will only be those obtaining at the time

of the study. Currents should be observed under as many different conditions of wave action and winds and for as long a period as possible in order to determine the strength and direction of the prevailing movement. In many cases these currents reverse from time to time under varying conditions but usually they are more predominant in one direction as indicated by a greater accretion at one side of a jetty, groyne or other shoreline structures. Also strong winds may produce a surface current moving in one direction while the lower body currents continue to move in the opposite direction and the true condition may not be detected unless the observations are carefully made. Where the studies are limited to a brief period of field work valuable information regarding the overall trend of currents in an area may often be obtained from the local long-time residents. A study of beach material may indicate its origin and thus indicate the long term direction of the currents.

5. Littoral Drift

Littoral drift is the material that moves parallel to the shore under the influence of waves and currents. This drift plays an important role in selecting the type, design and location of shore protective structures and a knowledge of its existence, direction of movement and magnitude is most essential before undertaking any work of this nature. The success of a groyne system depends upon an adequate littoral drift at the site. Other types of shore protective works would have to be more substantially built if a beach could not be maintained in front of them to absorb the initial shock of the waves.

The existence and direction of material movement may be determined from historical or geological evidence; by observing the accretion or erosion on either sides of jetties, groynes, and other structures; by the direction of trailing spits or by the migration of unimproved inlets. Valuable

information regarding this phenomenon may be obtained from available maps, charts, photographs and a study of conditions at existing shoreline structures. Conditions shown by maps, charts and photographs will be those existing at the time the surveys or photographs were made and may not hold for all seasons of the year but a comparison of these records covering a period of years will show the general trend of shore processes in that region. The direction of migration of unimproved inlets and the accumulation against one side of jetties or long groynes will indicate the predominant direction of drift.

The direction of littoral drift is governed by the angle of wave approach and/or the direction of the longshore currents. The predominent direction of the drift depends for the most part on non-storm waves. Over a long period of time more energy is spent on the shore by these waves than is contained in storm waves of shorter duration. Often individual severe storms or seasonal changes will bring about a reversal of the direction of drift and some accretion will occur on the alternate side of the jetties or groynes but the predominent direction of drift is indicated as being from the side which shows the greater accretion over a period of years.

The volume of littoral drift cannot be accurately measured but the approximate amount may be determined by means of periodic surveys of the build-up or accumulation at a jetty, groyne or similar structure along the shore. The amount of drift is computed using profiles prepared from successive surveys and the usual methods of computing earthwork. Generally a period of observations covering several years or more, and preferably for a full range of water levels, is required to give a fair estimate of the volume of drift by this method. Similarly the volume of drift may be determined by measuring the loss of material at a point of erosion and making due allowances for the percentage of this debris which would not form suitable drift material. Normally only the coarser materials such as sand and shingle remain in the drift zone while the finer components such as silts and clays pass out into deeper water beyond the influence of the shore currents.

Other methods employing water samplers and suitably designed aand traps are also used. This work is usually done in conjunction with current measurements and the combined results permit a rough estimate of the material movement to be made. Periodic dredging required to maintain inlets and harbour facilities will also, indirectly, provide some measure of the volume of drift in an area. At Toronto, for instance, the annual dredging of some 40,000 cubic yards of material is required to keep the eastern channel open to navigation.

The drift material is chiefly derived from the eroding shores and an important feature which affects the amount of littoral drift is the availability of unconsolidated material for erosion. Some drift material is also obtained from the sediments carried into the lakes by the tributary streams, but most of this material is top soil which comes down in the form of silt and is carried out into deeper water where it gradually settles to the bottom. There are some who claim that much of the drift material is derived from the lake bottom deposits. However, the Beach Erosion Board, Corps of Engineers, United States Army, claim from their observations and experiments that 80 per cent of the material movement takes place in water 6 feet and less in depth and that once material has settled beyond this depth there is little chance of it ever being returned to the littoral drift zone. Severe storms will disturb the bottom material in deeper water but these are rare and the amount of material obtained from this source is apparently insignificant.

6. Wave Forces

The action of waves breaking on the shore is all important in the study of shore protection. Much has been written about this subject but precise information is still lacking and it is difficult to understand why certain storms will build up a beach while others tend to destroy it.

It is generally recognized that waves are due primarily to wind action and that wave action is the energetic agent of shore erosion and a controlling factor in the design of shore protective structures. Since wave action is of such importance a knowledge of the prevailing and maximum wave conditions is mandatory for adequate design.

Whenever observations are made of lake currents and littoral drift, careful readings of wave data should be made and recorded. The data should be observed and recorded for both shore and offshore stations and should include; wave height, length, period and direction of approach with an estimate of the velocity and direction of the winds. Accurate determination of these factors is difficult but close approximations may be made by observing and averaging ten waves at intervals of 15 to 30 minutes. Offshore wave heights may be measured by observing the rise and fall on a weighted line or fixed pile. The period may be clocked and the velocity timed from bow to stern of an anchored boat. The length may be computed from the period and velocity, and the direction of approach read by compass. Near shore the measurements are easily obtained if there is a pier nearby. If not, poles may be set up at known intervals along a line perpendicular to the shore. The value of such observations increases directly as the length of time devoted to the study which will of necessity be limited by the cost involved. In any case, the waves should be observed at least once during each class of weather conditions.

Wave energy is proportional to its length and to the square of its height and a wave 200 feet long and 6 feet high would carry an energy of 57,600 foot pounds per foot at its crest.* It is evident that the wave energy increases rapidly with an increase in wave height but fortunately only a portion of this energy remains when the wave finally reaches

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* Wind Waves at Sea, Breakers and Surf. United States Navy Department. (p. 100).

the shore or a protective structure located in shallow water. Waves always break when the depth becomes insufficient for normal propagation of wave motion and in doing so dissipate much of their energy. Conclusions drawn from many observations indicate that waves will break before the depth of water becomes less than the wave height and in most cases it has been found that they do not break where the depth is greater than twice the wave height. It is therefore important to investigate the relations between the depth of water and the wave dimensions at a proposed site to insure that structures are not located at the "critical" depth or breaker zone where they would be subjected to the heavy impact of breaking waves. Normally the maximum wave force is exerted just above the still water level.

The most satisfactory method of obtaining wave forces is by actual instrument measurement of the forces at the site under representative conditions. Where time does not permit waiting for the storm period these forces may be estimated with fair accuracy through the analysis of long-term weather records and the use of wave hind-casting techniques together with other known physical factors for the site in question. Definite relationships between wave heights and wind velocities, duration and fetch have been developed. Thus, from the weather records and a knowledge of the physical features at the site it is possible to forecast the size of wave that may be expected at that point.

The Corps of Engineers, United States Army, made a statistical analysis of wave characteristics for selected points on the Lakes and in the absence of better data the results of these studies are shown below as a matter of interest. The values of wave heights given are so-called deep water values, that is, wave heights before any effects of refraction due to shallow water or other confinement have been felt. These are the expected once-a-year maximum wave heights,

period ranges, probable direction of wave approach and probable duration of the maximum wave heights at various points in deep water immediately adjacent to shore areas.

TABLE NO. 16

PROBABLE ONCE-A-YEAR WAVE CHARACTERISTICS

Locality	Max. wave height (feet)	Period range (seconds)	Direction of approach	Duration (hours)
Lake Superior				
Brule River	20	9 - 11	NE	6
Carver's Bay	27	11 - 13	NE	6
Little Lake	22	10 - 12	NW	8
Lake Huron				
North Point	9	5 - 6	NE or SE	6
Harbor Beach	13	5 - 7	E	5
Port Huron	8	4 - 6	N	9
Lake Erie				
Cleveland	9	5 - 6	W or WNW	6
Erie	9	5 - 6	W or WNW	6
Buffalo	11	6 - 7	W	8
Lake Ontario				
Olcott	9	5 - 6	W or WNW	6
Oswego	11	6 - 7	W or WNW	8

In addition to the above, several observations of the relationship between breaker dimensions and the pressures they exert were made in Lake Superior. The results are summarized below.

TABLE NO. 17

PRESSURES RECORDED ON SPRING DYNAMOMETERS FOR WAVES OF DIFFERENT DIMENSIONS

Height of wave (feet)	Length of wave (feet)	Max. pressure (lbs./sq. foot)
12	130 - 150	1,150
16	200 - 210	1,755
18	250	2,370

In 1915 the Toronto Harbour Commission made a series of wave pressure tests and for a 5.5 foot wave striking a vertical face pressures up to 640 lbs. per square foot were recorded.

7. The Effects of Wind and Ice

Winds affect the direction of wave approach and thus play an important part in determining the direction of littoral drift. They are also an important factor in the building of sand dunes and the lateral movement of sand along the beach. Wind records may be obtained from the meteorological office and generally there will be one or more recording stations close to the study area. Nearby airfields would also be able to furnish suitable wind data. In many cases there are wind records which go back a considerable number of years and from a study of these it is possible to obtain some idea as to why certain changes have occurred and what to expect in the future, particularly with respect to direction of the littoral drift, duration and intensity of storms and the time of year when storms may be expected.

For the purpose of tabulating wind data for beach erosion studies two types of wind-roses have been developed to show the prevailing wind movement, average velocities from each direction and the predominant direction of storm winds. These wind-roses are illustrated in Plate No. 9. The extent to which the wind investigation is carried will be determined by the general detail warranted for the study but in view of the wide influence of this natural factor it should not be ignored. Also this is one of the few pertinent factors in beach studies for which accurate records are usually available.

In the Great Lakes region ice may play an important part in shore processes and its effect upon protective works will influence the design of such works. During average years ice starts to form about the middle of December.

H. Spencer Clark

Scarborough Bluffs looking east from the Guild Inn. During the winter months a rim of ice often forms along the shoreline. This ice barrier is generally beneficial but shore protective structures are sometimes damaged by shifting ice floes during the break-up.

The initial ice sheet attains a thickness of 6 to 8 inches and extends some distance lakeward. This is usually followed by a breaking up of the ice by storms and wave action with the subsequent formation of thicker ice fields, hummocks and windrows. The ice fields migrate from place to place depending upon the direction of the wind. During severe winters shifting ice fields, forced ashore by strong winds are often piled up to heights of 20 feet or more. These ice masses do not, in general, cause damage to beaches or rip-rap and in many cases even provide additional protection against damage from storm waves. However, they often cause damage to other protective structures because of the tremendous load they superimpose on them, or by abrasive action and impact. Timber structures are particularly vulnerable to damage by this abrasive action of ice floes. Another type of ice damage is that caused by the buoyancy of ice. During severe winters large masses of ice will build up around shoreline structures. Then should a rise in water level occur these masses will be floated and, in turn, will often lift the structures with them. Rubble mound structures with their rough surfaces and loosely fitted blocks are subject to this type of damage. Ice usually becomes honey-combed and weakened about the middle of March and marked damage by ice seldom occurs after this date.

Information regarding the effect of ice on the shore and structures can best be obtained from local engineers and residents operating boats or owning piers or wharves in the area. Also a study of weather records, photographs showing winter conditions and an examination of existing shoreline structures for ice damage will indicate what type of protective work will best resist the destructive effect of ice.

8. <u>Degree of Protection Required</u>

The cost of providing full protection against wave damage is generally high and, in most cases, out of all proportion to the benefits to be achieved. Thus, economic

considerations usually determine whether the work shall be such as to provide complete and permanent protection; protection against ordinary storms only; or whether it shall merely be of a temporary nature to provide some measure of relief during a critical period. With the lesser protection for ordinary storm conditions, some damage would occur during exceptional storms but as long as the work is structurally sound it would prevent complete destruction of shore properties. For all work, other than temporary, the structures would be designed to withstand the maximum conditions and economic considerations must not be allowed to dictate or otherwise influence in this aspect of the work.

The ultimate use of the adjacent land should also be considered in planning a protective system for an area. Often the present land use may not warrant complete protection but where it is apparent that the area will subsequently be developed as residential or industrial lands then the provision of a greater degree of protection at the outset might be justified.

9. Improvement Desired

The result to be achieved is an important factor governing the selection of type and design of a shore protective method. Generally shore erosion at a given locality may be halted by any one of several methods and the final selection will be that which will best serve the intended purpose at the lowest cost. However, most protective works may be modified to serve a dual purpose and thus provide increased benefits and lower the cost - benefit ratio.

Probably foremost in this regard is the beach fill method which provides valuable recreational facilities as well as protection. This method is particularly suitable in densely populated areas where beach facilities are at a premium. Similarly with other types of protection, with their variety of designs and flexibility, it is usually possible to select a type which may be used to cater to the needs of the area in addition to providing the necessary protection.

Ocean City, New Jersey. This beach reclamation project was one of the greatest sand filling operations ever undertaken. 1.5 million cubic yards of sand were pumped in to restore a 2 mile long stretch of beach which had almost completely disappeared

Upper View. This area between the boardwalk and the buildings has been raised about 8 feet above mean low water Prior to filling, the ocean tides reached the buildings on the right

Lower View. A 200 foot width of beach has been created beyond the boardwalk which will protect the shorefront properties from storm waves and provide a valuable beach area

8

TYPES OF SHORE PROTECTION

It has been pointed out that there is no stereotype method of shore protection which might be applied to all sections of the Great Lakes or even to all localities within any one section. If it were possible to develop such a method which would provide adequate protection to any locality under all conditions shore protection would present few difficulties. But the problem is not that simple and many types must be considered in the light of local conditions and the results to be achieved. Each of the different types has its own inherent advantages, disadvantages and limitations and these attributes generally dictate the method and degree of protection to be employed.

On the shores of the Great Lakes there are many examples of structures and devices used to protect shoreline properties. These vary widely in design, nature of construction and type of materials used. Many of the structures were built some years ago when the water was low and were probably thought quite substantial and secure but with time and particularly high water, many of these structures have been destroyed and the erosion which they prevented has begun again. In other instances works which have survived have failed to accomplish what was intended of them and have often been the means of accelerating the erosion on adjacent frontages. Out of it all, it is quite apparent that half-measures and inadequate structures are a waste of money and often contribute to, rather than prevent, erosion.

1. <u>Beaches and Beach Fills</u>

A beach is a temporary deposit of coarse detrital material which has been eroded from the shore cliffs

and is slowly making its way into deeper water. When the shore processes responsible for beach development are in adjustment and sand and gravel is being replaced as rapidly as material is being removed then a profile of equilibrium is created. Under such ideal conditions a beach is maintained naturally and forms an effective barrier between the destructive waves and the uplands which they are tirelessly seeking to destroy. This is the natural method of shore protection.

However, such ideal conditions seldom exist in nature and in order to maintain beaches of sufficient size to keep the waves away from eroding the lands fronting the shore, artificial replenishment is often used whereby beach material is supplied at a rate equal to that at which it is being removed. This material may be supplied either through "feeder-beaches" or by applying it directly along the shore where it is required. Feeder-beaches are simply stock-piles of material placed at the up-drift end or at suitable intervals along the beach. They augment the littoral drift and provide continuous nourishment through natural shore processes. In some localities it may be found more expedient to apply the sand more or less uniformly over the beach throughout the entire length under consideration rather than depend upon littoral currents for the distribution.

To be effective sufficient material must be placed on the beach to provide a stable beach slope of approximately 1 on 30, or flatter if possible, with the backshore area raised to an elevation beyond the vertical limit of wave uprush which, for the Great Lakes, would be about 7 feet above the high lake level. Since the maximum lake levels are about 2 feet above low water datum for Lake Superior and about 5 feet above low water datum for Lakes Huron, Erie and Ontario, the elevations above low water datum to which a beach fill should extend are:

TABLE NO. 18

ELEVATION OF BEACH FILL *

Lake	Elevation above low water datum for permanent protection
Superior	9
Huron	12
Erie	12
Ontario	12

In addition, for permanent protection a berm width of at least 50 feet should be provided at this elevation beyond the established beach slope. From the typical beach fill sections shown on Plate No. 10 it will be noted that sections at time of placement would be those indicated by the broken lines but wave action would ultimately produce the flatter slope line shown.

The principal advantages of this method are: (1) it provides protection without impairing the recreational value of the beach; (2) the material is beneficial as long as it remains in the littoral drift zone and thus protection may be extended over many miles of shoreline and, (3) it takes advantage of the natural shore processes and in effect acts as an aid and guide to nature rather than directly opposing her.

The principal disadvantages are: (1) it requires an adequate supply of economically located beach material; (2) it cannot be used economically where deep water exists near shore; (3) it is restricted to areas where the losses of beach material are comparatively low, and, (4) it is impractical for the protection of short isolated reaches of shoreline.

The cost of this method of protection will vary considerably from place to place depending upon the configuration of the existing beach, the rate of loss of material from that

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* Data prepared by the Corps of Engineers, United States Army.

beach, the width of berm desired and the location of available beach material. Generally speaking, the wider the berm and the flatter the beach the better, but a fill giving a 50 foot berm and a beach slope of 1 on 30 is considered satisfactory. On this basis it is estimated that, on the average, 140 cubic yards of material would be required per lineal foot of beach. In view of the many variable factors influencing the cost of work of this nature it is difficult to state a firm cost but generally fill may be obtained for approximately 85 cents per cubic yard in place and allowing 25 per cent for overhead, engineering and contingencies the unit cost per lineal foot would be approximately $150.00.

The life of a beach fill would be dependent upon the rate of erosion and, as it has been pointed out above, would not be feasible where the loss through erosion is excessive. However, for areas of high recreational value this method provides a practical solution, if the annual loss is not greater than 5 per cent.

The annual costs would vary with the location and the erosion losses. Where this loss is comparatively small maintenance would probably be in the form of feeder-beaches established at 3 or 4 year intervals as it would not be economical to provide small amounts of fill annually. Because of the large quantities of fill involved in this method, the only sources from which it could likely be obtained at reasonable prices would be from the lake bottom or from sand dunes along the shore and great care should be taken in outlining the borrow areas to ensure that the removal of the material will not adversely affect the shoreline in that vicinity.

2. Groynes

A groyne is a fence or pier-like structure extending from the shore usually perpendicular or nearly so to the shoreline, to trap or retard littoral drift and modify

offshore currents and wave action. Groynes are the most widely used shore protective measure and when properly designed have proved to be the most effective means of stabilizing a shoreline or creating a beach where there was an adequate littoral drift. Both permeable and impermeable groynes constructed of timber, steel, stone, concrete or combinations thereof have been used but, in general, the impermeable or sand-tight types have proven more successful than the permeable or semi-solid type. To be effective groynes should be used in a group or system rather than as isolated units and should be so designed to retain that amount of littoral drift which will provide a satisfactory beach and allow the surplus to pass on to build up the beaches to the leeward.

The permeable type groynes were designed to permit partial flow without changing the normal path of the shore currents. They were intended to act as a check on the littoral drift and to obtain a more even distribution of sand on both sides of the groynes. They have shown some success in this respect in areas where there is a large amount of littoral drift.

The design of a groyne should be based as nearly as possible on maintaining or restoring natural beach conditions. The inner end of the groyne must be well keyed into the high land at the rear or securely fastened to a bulkhead if there is no high well consolidated land within a reasonable distance of the shoreline. The top of this inner section is usually set at the average elevation of the natural berm. Where groynes have been effective those which have heights at their landward end not exceeding 5 or 6 feet above mean low water have retained material on their up-drift sides without completely intercepting the littoral drift. The length of a groyne will vary considerably but as a maximum they should not be extended beyond a depth of 6 feet below mean low water. Since about 80 per cent of the littoral drift under normal

Permeable timber groynes on Lake Ontario near Winona. The Committee noted that permeable groynes were generally unsatisfactory

Close-up view of groyne showing construction details This groyne has failed to trap any beach material and is in danger of being outflanked

Accretion at this groyne is evidently due to the remains of the old rock-filled timber crib groyne on the right.

(Hamilton Spectator)

Rubble stone groyne on Lake Ontario near Vineland. Where stone is available this type of groyne is conparatively inexpensive. Properly constructed, they are effective in areas where groynes may be used but because of their unsightly appearance and hazardous nature they are not entirely suitable for public beaches.

weather conditions occurs shoreward of this depth there is little to be gained by going beyond this point while there is always the danger of cutting off completely or diverting the littoral drift into deep water by exceeding it. The top of the outer end is usually fixed at mean lake level. This is a compromise between the elements and the difficulties of construction. It would be well to keep this outer end below mean low water where it would still serve to check the wave currents but would not be subject to the full force of the wave above the still water level where the maximum force is exerted.

The slope of the groyne should be slightly less than the natural slope of the beach in order to encourage as flat a beach as possible. Since this slope will be fixed by the difference in elevation between the inner and outer ends and the length of groyne determined for that particular site it is evident that some compromise has to be made in the design to obtain the best over-all result.

The spacing between groynes is governed by a general rule based on many observations of groyne systems namely: that the ratio between the length of groyne and the shoreline distance to the next groyne should be between 1 to 1 and 1 to 3. Spacing less than 1 to 1 does not injure the beach but is unnecessary. Spacing greater than 1 to 3 appears to be ineffective in holding a good beach. Within these limits the spacing is determined by the direction of approach of the storms causing the most severe erosion. After the length of a groyne has been determined by offshore conditions, a line should be drawn through the end of the groyne parallel with the direction of storm wave approach; the point where this line intersects the shoreline is the proper location of the next groyne and this procedure will determine the proper spacing. This spacing will not always fall within the above ratios and if not, the nearest one should be used. Also it is obvious that the spacing may be increased slightly by tilting the line of the groyne away from the direction of the storm approach.

This has been tried in several instances and after several years of observations it has been noted that where groynes have been swung from 10 to 15 degrees off the normal line they have produced a more uniform build-up on either side of the structures.

The detailed design of the groyne will depend upon location, exposure to wave action, intended purpose and the construction method used. Where sheet piling is used the sheets should be interlocked and well bound together with wales and supported at suitable intervals by long piles to withstand the wave and ice action. The sheeting should have approximately two-thirds penetration under the most severe erosion expected to occur. In some localities it may not be necessary to use the long supporting piles but their omission is not recommended unless good penetration into hard material affords a natural anchorage. Stone groynes should be constructed of stone weighing not less than 3 tons and preferrably 5 tons or more unless each piece may be keyed in position to prevent damage under icing conditions. They should have a compacted core of crushed or quarry-run stone to make them sand-tight and a suitable foundation to prevent the structure from settling. If subsidence does occur there is the danger of the heavy face stones opening up and exposing the core material which would quickly be washed out by the waves. On soft unconsolidated material a mat of crushed stone or facines is often used to provide a suitable footing. A typical stone groyne should have a minimum top width of 5 feet with side slopes of 1½ to 1.

Requirements for concrete groynes are much the same as those for stone groynes. It is important that these heavy structures have a good foundation to prevent settling, that they have a wide base for stability and sufficient weight to hold them in place.

Where there is no solid land within a reasonable distance of the shore a bulkhead is often used to anchor the

Timber groyne and bulkhead system on Lake Erie near Erieau. Compare wave action in foreground to that in background.

(*W. L. Rice*)

Waves breaking against an exposed section of the bulkhead. Backwash from waves will likely prevent the formation of any beach here

Where bulkhead is back from the water's edge or where groynes are used alone, the waves are quietly dissipated by the gently sloping foreshore.

Timber groyne and bulkhead system protects County Road near Brights Grove on Lake Huron. Growth of beach material against one of the groynes is shown in photograph below.

landward ends of the groynes to prevent their destruction through flanking. Usually the bulkhead will be of the same type of construction as the groynes and the requirements outlined above will apply. The bulkhead is usually set at the same elevation as the top of the inner ends of the groynes or it may be higher if a higher berm to the rear is desired. It is important that the bulkhead be impervious to prevent removal of the back-fill material and that it be of sufficient structural stability to withstand the pressure from the land side should the lake side be exposed to the low water level. The basic factors governing the design and placing of the bulkhead will be similar to those outlined in the section on "seawalls and bulkheads".

Where bulkheads are used in conjunction with groynes there is a tendency to shorten the groynes but this is not recommended since the primary purpose of this method is to create a beach which will act as a buffer to trip the waves and prevent their breaking directly against the bulkhead. If sufficient beach does not exist the backlash from the waves breaking against the bulkhead meeting the incoming waves creates such a turbulence that it not only retards the building up of a beach but may conceivably cause the loss of any existing beach. The bulkhead should be regarded as a last line of defense; an added precaution against exceptional storms that may be expected.

Groynes provide upland protection by the interception of some part of the material in the littoral drift or by modifying the rate of littoral drift through a resultant re-orientation of the shoreline. Their principal advantages are: (1) they provide protection without loss of use of the beach; (2) their effect may spread over considerable lengths of beach; and (3) where groynes would be effective, protection can generally be provided at a lower cost by their use. Disadvantages in the use of groynes include: (1) they are pro-

bably not as positive as seawalls or breakwaters for continuous upland protection; (2) only suitable in areas where there is a substantial littoral drift; (3) should not be used as isolated units and therefore are restricted to the protection of comparatively long reaches of shoreline; and (4) unless carefully laid out they may rob the downdrift beaches and further aggravate their erosion problems.

The determining of where groynes can be effectively used, the type and spacing can only be made after a survey of the area and an analysis of the possibilities for the use of other protective methods. Several types of groynes are shown on Plate Nos. 11 to 19. With the exception of the permeable groyne shown on Plate No. 12, all of these groyne types have been effective at locations on the Great Lakes. The permeable groyne system, located on Lake Ontario near Winona, was not entirely satisfactory and is presently being altered. The groynes shown are by no means the only acceptable types but are considered typical for cost comparison purposes. The following table gives the costs for groyne structures built, or recommended for construction, on the shores of the Great Lakes in recent years and which are considered to be representative of present day costs.

When observed by the Committee each of these groynes appeared to be equally effective.

Typical cantilever steel sheet piling groyne

Typical timber groyne

Typical steel sheet and timber piling groyne

This massive groyne constructed of large quarried stone blocks protects the beach at Painesville Township Park, Ohio.

Avon Lake Village Park, Ohio. This precast concrete block groyne with its trim lines is suitable for public beach areas.

(See fig. 3, Plate No. 16)

General view of the groyne system at Avon Lake Village Park, Ohio. Landward ends of the groynes are protected by a concrete block revetment to prevent flanking.

TABLE NO. 19

COST OF TYPICAL GROYNE STRUCTURES

Plate No.	Type	Length (feet)	Total Cost	Cost per foot
11	Timber piling (solid)	108.0	$4,346	$40.24
12	Timber piling (permeable)	100.0	8,500	85.00*
13	Steel sheet piling	115.5	4,951	43.20
14	Steel sheet and timber pile	130.0	4,478	34.45
15	Precast concrete block	100.0	4,693	46.93†
16	Rubble mound (Fig. 1)	180.0	9,190	51.06
16	Precast concrete block (Fig. 2)	102.0	6,324	62.00
16	Precast concrete block (Fig. 3)	Estimated		50.40
17	Timber Bulkhead and Groynes	Estimated		40.00**
18	Concrete Bulkhead and Groynes	Estimated		40.00††

* Based on average of 1952 prices tendered for the construction of 3 additional groynes. Original groynes built during 1950 cost approximately $7,000 each.

† Based on the total construction price of $93,861 for 20 - 100 foot groynes (Eastern Beaches, Toronto, 1952).

** Cost per foot of shoreline protected based on Engineer's 1952 estimated costs for 3,590 lineal feet of shore protection, Mersea Township, Lake Erie.

†† Cost per foot of shoreline protected based on Engineer's estimated costs for 2,735 lineal feet of shore protection, Mersea Township, Lake Erie.

First of 23 precast concrete block groynes to be installed on the Eastern Beaches, Toronto Groynes are 100 feet in length and will be spaced at 100 foot intervals

Brushwood mats used to provide a firm footing for the heavy blocks

Precast blocks ready for assembly. Blocks weigh 11 tons each and vary from 3 to 5 feet in depth.

3. Seawalls and Bulkheads

Probably the most positive means of protecting a shoreline against erosion is a seawall adequately designed and constructed with a substantial safety factor to withstand the heaviest seas and damage by ice. They are necessarily massive and expensive and because of their high cost they would be limited to highly developed areas where it is essential to hold a fixed line or where other shore protective measures are not feasible. They limit the shoreward movement of the high water line but under severe wave action generally promote the removal of sand from the beach in front by wave wash. Under normal wave action some sand may be returned to the beach but a seawall has no capacity to retain sand and therefore has no value in stabilizing a beach.

Bulkheads are used for the same purpose as seawalls but are generally of a lighter construction and less expensive. They are used to retain backfill along the shore and to prevent flanking of a groyne system. Like seawalls they have no value in themselves for retaining or promoting a beach.

The factors governing the design and siting of seawalls and bulkheads are the same so far as their effect on the beach is concerned. These factors are: character and extent of development in the area to be protected; exposure to wave action; character of wave action; presence or absence of sand dunes or bluffs; water level fluctuations; character of the subsurface materials; general slope of the beach; width of beach desired in front of the structure; and the degree of protection required. The economic factor must also be taken into consideration but in no case should it be allowed to dictate the height or strength of the protective structure or otherwise influence its structural stability. The line of the seawall or bulkhead should, in general, be kept as straight as possible and if changes are made necessary by a change in the

Stepped-face seawall protecting the Shoreline Drive, Chicago, Illinois

Construction picture showing the difference in wave action against vertical-faced cofferdam as against completed section of stepped-face seawall

Portland Cement (

direction of the beach they should be accomplished by smooth gradual curves. Sharp angles or set-backs cause a concentration of wave action at these points and increase scour. The placing of structures of this type is very important and where possible they should be set as far back from the high water line as local development will permit, to take advantage of the natural conditions favourable to wave dissipation. The need for a protective beach in front of seawalls and bulkheads cannot be stressed too strongly and should be recognized initially by resisting the temptation of trying to reclaim land already lost. Waves against a vertical or nearly vertical structure set up a tremendous turbulence and cause severe scouring action in front of it. It is also important that the ends of seawalls and bulkheads be adequately protected against flanking. The ends should be turned back and well keyed into the solid ground to the rear or protected with heavy rip-rap or sheet piling.

Seawalls and bulkheads have been constructed to various designs employing steel sheet piling, concrete, timber piling, timber cribbing filled with stone, or stone. Of these materials concrete and steel sheet piling are the ones most commonly used. Where abrasion due to sand carried in suspension or ice wear is severe, concrete walls may well be faced with granite or other hard stone.

In all cases the fundamental requirements for wall stability must be observed but generally a larger factor of safety is allowed since it is impossible to evaluate accurately the numerous variable forces to be dealt with. Seawalls and bulkheads prevent erosion by their sheer ability to withstand the direct assault of the storm waves and therefore must be structurally sound.

The principal advantages are: (1) they provide positive protection and generally permit a more extensive use of the area so protected; (2) they maintain a fixed alignment of the shore; (3) they are adaptable to local spot protection with

The Toronto Island Seawall is a typical example of the curved-face seawalls. Three foot "splash" wall was added last year to provide a greater degree of protection

Seawall at the Victoria Park Avenue Pumping Station, Toronto

Photograph showing the 3 foot splash wall recently added to the Toronto Island Seawall.

Small seawall at Port Credit, showing evidence of abrasion by wave tossed stones.

a minimum of danger to the adjacent frontages. The main disadvantages are: (1) they are expensive and therefore are limited to areas of high value; (2) they are generally detrimental to the maintenance of a beach; and (3) they provide no protection to the adjacent areas.

There are countless efficient types of seawalls and the final selection of the type to use in any particular area would depend upon the results of a detailed study of all the natural factors in the area. Some type of stepped wall may be desirable at a public beach to provide access to the beach while at other areas the availability and cost of the component materials would be the deciding factor. The pertinent features of several different types of seawalls are shown on Plate Nos. 21 to 25, and the estimated costs for each are given in the following table.

TABLE NO. 20

COST OF TYPICAL SEAWALLS AND BULKHEADS

Plate No.	Type	Unit Cost per lineal foot
21	Stepped-face	$160.00
22	Curved-face	165.00
23	Vertical-face	290.00
24	Cellular Steel	265.00
25	Steel Sheet and Timber	135.00

4. Revetments

A revetment is a sloped facing usually of stone or concrete, used to sustain an embankment. This method of protection has been used extensively and examples are to be found in almost every community throughout the Great Lakes. In most cases, common rubble such as broken concrete and brickwork or industrial wastes were simply dumped over the bank in an effort to halt the erosion and while much of the material was unsuitable for permanent protection it has provided some measure of relief.

Revetments perform essentially the same function as seawalls and bulkheads in that they both provide a non-erodible barrier to protect the upland area against storm wave action and the factors governing the siting of seawalls and bulkheads, as outlined above, apply to this type of protection also. In the design of an individual structure it is important that the top of the revetment be high enough to prevent over-topping by any but the extremely rare storms and that the toe be protected to insure against undermining. Revetments are sometimes used in conjunction with groynes to prevent the latter from being damaged by flanking and if a sand accumulation by a groyne system can be depended upon to trip the waves before they reach the revetment then the height may be reduced accordingly. The face slope of the revetment should be carefully selected to insure stability under the wave forces to which it will be exposed.

Stone revetments such as those shown on Plate No. 26 are the most common type of revetment in use. The essential elements of stone revetments consist of cover stone of sufficient size and weight to resist disturbance by wave and ice action and a filter or filters of smaller stone under the cover stone designed to decrease the permeability of the structure and prevent undermining by removal of bank material. The smaller stone can be prevented from passing through the revetment by the proper selection and placing of material for the filter. With close fitting cover stone a single layer of unscreened crushed stone approximately 4 inches and under would be sufficient but with random-dumped cover stone where some of the voids might be quite large it would be necessary to have two or more layers varying from fine to coarse, each layer being of such a size that it would contain the material below it and finally the whole being contained by the heavy cover stone. Grouting is frequently used to seal up the voids in the cover stone as a guard against the washing out of the

bank or core material and is also useful where the individual cover stones are too light to resist displacement by the waves and ice.

The preferred type of cover stone is rectangular quarried stone blocks weighing from 3 tons upward. However, the heavy angular quarried stone of odd sizes and shape is quite suitable and is the type most commonly used. If carefully constructed of a durable stone this type of revetment should have a long life. Boulders because of their smooth surfaces and roughly spherical shape are not suitable unless grouted in position. Precast concrete blocks are often used in place of stone for the facing. In some localities they may be obtained at a lower cost than stone and in many ways they are superior to the stone. Concrete blocks could be cast on the job and to the size and shape best suited for the particular job.

Continuous slab-concrete and asphalt revetments have also been used but they are not common and have generally been limited to river bank protection. Recently a short length of shoreline at New Toronto was provided with a slab-concrete facing more or less as an experiment but its history is too short to permit any conclusions as to its service in time of storm, or ultimate efficiency. It is a continuation of a stone revetment built several years ago and thus it will provide a good comparison of the two types. The cost of the concrete revetment was substantially greater than that for the stone work.

The principal advantages of revetments are: (1) they require a minimum of preliminary investigation; (2) their ease of construction and maintenance; (3) their ability to absorb waves without causing an undermining reaction; (4) they are suitable to spot protection with a minimum danger to adjacent properties. The principal disadvantages are: (1) their protection is only local and does not extend to the adjacent properties; (2) they have no ability for holding or

View of the eroding bluff at the Ontario Hospital grounds, New Toronto, before any protective work was undertaken.

Revetment construction. Large angular stones were placed along the shoreline and backfilled with quarry-run stone. Approximately 2,000 tons of stone in place at this time.

Completed revetment with 8,000 tons of stone in place. About 400 feet of bluff were protected by this work at a cost of $13,000.

(Photographs by W. L. Rice)

Reinforced concrete slab revetment at Ontario Hospital, New Toronto. This type of revetment cost $58 per linear foot.

Rubble stone revetment, Port Credit.

creating a beach; and (3) they are generally limited to those areas where there is a comparatively high bluff or escarpment.

The cost of these structures will vary considerably from place to place depending upon the availability of materials at the proposed site. As pointed out above, stone is the most common material used and in most cases where it has been used it appears to be both serviceable and satisfactory. Along the south-westerly shore of Lake Ontario where quarries are close at hand random-dumped stone revetments have been built at costs ranging from $1.75 to $2.50 per ton. For another job in Toronto carried out in the fall of 1951, which involved the placing of 3,000 tons of quarried stone blocks the price quoted was under $6.00 per ton. But generally the present day prices along the Great Lakes appear to vary from $8.00 to $12.00 per ton. It is estimated that approximately 4 tons of stone are required per foot of shoreline and therefore the unit cost for this type of protection would be about $40.00. The length of haul and the handling by derrick necessary to place the individual stones will greatly influence the final cost.

Some of the more common types of revetments in use today are shown on Plate No. 26 and these together with their estimated costs are given in the table below.

TABLE NO. 21

ESTIMATED COSTS FOR TYPICAL REVETMENTS

Plate No. 26 Fig. No.	Type	Unit Cost per lineal foot of shoreline
1	Quarried Stone	80.00
2	Capped Rip-rap	70.00
3	Placed Rip-rap	110.00
4	Random-Dumped Rip-rap	55.00
5	Concrete Block	80.00
6	Slab Concrete	90.00

5. Breakwaters

A breakwater is a structure, usually built off shore and parallel to it, employed to break waves and prevent their incidence on the adjacent shore. They serve a dual purpose by first, preventing the destructive waves from reaching the shore and, secondly, creating a sheltered area suitable for bathing, boating and other water sports. Breakwaters have been used quite extensively on the shores of the Great Lakes and have proved their worth at many localities. Probably the best and most widely known example is the "Sunnyside"breakwater at Toronto. Built some 30 years ago this 3½ mile long structure has provided adequate protection in spite of the extreme high water levels which have obtained in recent years.

The preliminary work necessary for designing a breakwater starts with securing information on the physical characteristics of the locality. Investigation of the foundation conditions should be obtained by probing or drilling. The extent of this investigation will be determined by the resulting weight per square foot of the proposed structure and its ability to withstand irregular settlement without serious injury. Generally bottom material ranges from solid ledge rock to soft mud and each material requires its own treatment. The probability of undermining must be recognized and given careful consideration. When the bottom is firm with a good bearing power and is not susceptible to scour from currents down the face or along the structure then the breakwater may be set directly on the natural bottom. However, such conditions seldom exist on lake bottoms and usually a prepared foundation of stone or fascine mats or piling sufficient to support the designed load is required.

In preparing the layout and design for breakwaters such factors as exposure to wind waves, currents, depth of water, variations in water levels and icing conditions must all be taken into account. Wave force is the controlling

factor in the design and where possible the structure should be so located as to take advantage of any natural conditions favourable to wave dissipation. This force because of its complex nature is not readily measureable and thus much will depend upon local observations of the characteristics of the waves covering representative conditions supplemented by data on wind velocities, duration and direction obtained from the nearest meteorological station. Due to the uncertainty of the various forces acting on breakwaters, these structures were generally designed with a wide margin of safety resulting in higher costs. However, with the development of laboratory equipment and techniques for model studies of this problem these forces may now be evaluated more accurately and the structures designed accordingly.

The height of the structure will depend upon the height of the waves and the degree of protection required. It may not be necessary to completely obstruct the waves but the volume of water thrown or spilled over the top should not be sufficient to cause undue disturbance along the shore to be protected. Where waves are only partially obstructed the deck of the structure must be designed to take the impact of the falling water and the inside toe must be safe from scour caused by the overflowing water running down the inner side. An excessive height of structure would be required to completely block storm waves for all conditions.

In selecting the type of breakwater these principles should be kept in mind: breakwaters because of their position must have good strength and stability to withstand the external forces and must be safe from failure by overturning, sliding, undermining and disintegration from internal pressure which sometimes develop inside of structures due to the hydrostatic pressure from waves. The type should be the most economical considering both the initial and maintenance costs; and it should be the most suitable under the existing

conditions to provide the degree of protection required. Breakwaters require large quantities of materials and often the availability of suitable materials locally will dictate the type of construction to be used.

From a practical standpoint breakwaters may be classified under three general headings: (1) the vertical or wall type, (2) the rubble-mound type and (3) the composite type which is a combination of a wall and mound.

The wall type includes all structures in which the exposed face is vertical or slightly inclined. Structures in this group are commonly built of masonry, concrete, timber cribs, concrete caissons, timber or steel sheet piling. Masonry and concrete are suitable where the lake bottom affords a firm bed and the depth is at least twice the design wave height. Structures of this type require very little maintenance. Timber cribs are suitable for use in fresh water and will last indefinitely if kept submerged. Concrete caissons are heavier and require less material than rubble-mound structures. Steel sheet piling breakwaters are suitable in depths up to 40 feet and may be used on practically any kind of foundation where steel piles can be driven. Also when foundation conditions are suitable steel sheet piles may be used to form a gravity type breakwater without penetration of the piles into the bottom.

The rubble-mound types are adaptable to any depth of water and nearly all foundation conditions. They are generally trapeizoidal in cross-section with $1\frac{1}{2}$ to 1 side slopes and a minimum top width of 10 feet. The weight of cover stones used varies from 5 to 10 tons. Natural quarried stone is generally used and the quality of the stone is of prime importance. Stone for breakwaters should have a high specific gravity, be dense, hard, tough and not subject to disintegration when exposed to air or water. In some cases precast concrete blocks of various sizes and shapes have been used for this type of structure when natural rock was not available at reasonable cost. Chief advantages of this type are that they

A section of the Toronto Breakwater at the entrance of the Western Channel

The Toronto Island Breakwater is a good example of the rubble stone mound type of breakwater

Aerial view showing a section of the Toronto Breakwater at Sunnyside. This 3½ mile long structure was completed in 1924 at a total cost of $4,500,000. In conjunction with the building of the breakwater, practically the whole area from the Canadian National Railway right-of-way to the present shoreline and from Dowling Avenue west to the Humber River was built up with sand fill dredged from the lake bottom. Since its completion the breakwater has proved its effectiveness in protecting the shorefront properties from storm waves and has provided a valuable calm-water area for aquatic sports.

may easily be repaired if damaged and that they produce less reflected wave action than the wall types as much of the wave energy is absorbed by the sloping face.

Breakwaters of the composite type are usually constructed with a mound as the foundation or main structure surmounted by a wall superstructure with a vertical, stepped or slightly inclined face. This type has been used quite extensively along the American shores and probably the most common type of structure used in modern practice. The rubble-mound section should be placed 6 to 12 months in advance of the superstructure to allow settlement and permit adjustment of the mound by wave action.

Another type employed for shore protection is the submerged breakwater. At many localities the stability of existing beaches was considered to be the result of the stilling action of a submerged reef on the approaching waves and attempts have been made to create this condition artificially by the construction of submerged works generally paralleling the shore. Observations of such works have been limited but apparently they are effective in preventing the lakeward movement of fill material and in one instance at least, a breakwater of this type appears to have aided in creating a beach. There are four such breakwaters in Chicago, constructed either of steel sheet piling or of rubble-mound. They are located approximately 500 feet offshore and parallel to the shoreline in water depths of 13 to 20 feet. The top elevations of the breakwaters vary from 2 to 6 feet below low water datum. Their primary function was to retain sand fill landward without creating a land-locked pond. The top of the fill at the submerged breakwaters was generally from 3 to 5 feet below the top of the structures. Insofar as can be determined these structures have retarded the offshore movement of material although some scouring along the sides of the vertical steel sheet piling breakwaters has been noted. In

addition to retaining sand fill they are designed to act as a baffle in breaking up the waves crossing the structure. Obviously, the reduction of wave energy shoreward of the breakwater reduces the movement of material.

Subsequent preliminary model studies of these structures have indicated that they will decrease wave height and wave action on the shore, that the vertical wall type appears to be the most effective and that for effective storm protection the structure should be at least 0.8 of the still water depth.

The submerged breakwater has several advantages over the higher exposed type. Being lower they require less material and since they are not exposed to the full fury of the waves they would not have to be as substantial and therefore are somewhat less expensive. They may be used to reduce beach slopes artificially which in turn will reduce the wave action on the shoreline. However they do not provide the same degree of protection as the higher breakwater which would intercept a greater portion of the storm waves.

In the final analysis experience will limit the number of types which have generally been found practical in a given locality. Through a study of the various designs and histories of breakwaters in the vicinity or in similar locations it will be possible to limit the preliminary design work to two or three types which would be suitable to provide the required protection. At this point comparative cost estimates taking into consideration both the initial and maintenance costs would determine the final selection. In no case, however, should the costs be the sole criterion for determining the type of breakwater to be used.

The principal advantages of breakwaters are: (1) they provide protection without impairing the usefulness of the beach; (2) they create calm water areas suitable for recreational purposes; and (3) they may be used to reduce the

Submerged breakwater at Chicago, Illinois showing its stilling effect on the waves.

Breakwater at Port Stanley. Some idea of the size of these structures may be gained from this photograph.

beach slope to make the artificial building of a beach economically feasible. The disadvantages of this method of protection include: (1) cost of breakwaters generally limit their use to property of considerable value; (2) depending upon their distance offshore, breakwaters have to be somewhat longer than the actual length of shoreline to be protected; there is a possibility that any littoral drift might be cut off through the reduction of the wave forces along shore; and (4) involves the risk of exposing costly floating construction equipment to the hazards of storms.

Typical sections of several breakwaters which have been constructed on the shores of the Great Lakes are shown on Plate Nos. 27 to 30 and the following table lists the estimated present day costs per foot for each of these types. The costs given are considered to be average for the Great Lakes area but it should be recognized that such costs will vary widely from place to place depending upon the accessibility of materials, the risk element involved due to the hazards of storms and the distance from suitable harbour facilities.

TABLE NO. 22

ESTIMATED COSTS FOR TYPICAL BREAKWATERS

Plate No.	Type	Unit cost per lineal foot
27	Rubble Mound with facines	$240.00
28	Concrete and Timber Crib	475.00
29	Concrete Piling	220.00
30	Submerged Steel Sheeting	150.00

6. Jetties

A jetty is a structure extending out from the shoreline at the mouth of a river or entrance to a bay to aid in deepening and stabilizing a channel for the benefit of navigation and as such this type of structure is beyond the scope of this report. In accomplishing their purpose, however,

these structures interfere with the off shore currents and littoral drift and it was considered advisable to mention them to indicate that certain precautions are necessary in planning works of this nature.

Jetties are similar to impermeable groynes but are larger in cross-section, of heavier construction and of greater length. Because of their greater length they have a pronounced effect on the littoral drift generally trapping a large fill on the updrift side with resultant deterioration of the shoreline to the leeward. The jetties at the eastern entrance to the Toronto Harbour are a good example of this condition. Here, the easterly jetty has trapped a large amount of fill to the east, building the shoreline out almost to the end of the jetty. At this stage the littoral drift flows around the end of the structure and is either deposited in the channel or carried through into the bay to form a delta at the inner end of the channel. This material would have continued on along the shoreline to help stabilize the beaches to the west if the inlet had not intercepted it. Jetties may also have the effect of diverting the littoral drift out into deep water.

Similar conditions exist at many points along the Great Lakes and sea-coasts. In several instances in the United States a solution has been provided through the installation of pumps or "fixed dredges" to transfer the material which tends to accumulate on the updrift side across the channel to the downdrift side. This is a more or less continuous operation with the pumps being regulated to balance the natural flow of littoral drift. From the few years of experience it appears that this method is more efficient than the periodic dredging with the use of floating equipment. Besides keeping the channel open the material is passed on to nourish and maintain the beaches beyond the channel. The benefits of this sand fill may extend for miles down the shoreline and in proportion to the length of protection afforded, the cost of this method is exceedingly small.

It is not proposed to go into the details of these installations but they are mentioned here to emphasize the necessity of giving serious consideration to their ultimate effect on the adjacent property during the designing of such works. Structures of this type cannot be modified to serve the dual purpose of beach preservation and navigational aid but in many cases it would be an advantage to install a sand pump to offset any injurious effects which might be caused by such structures.

9

MISCELLANEOUS PROTECTIVE METHODS

In addition to the orthodox methods of shore protection such as beach fills, groynes, seawalls, bulkheads and breakwaters, many other devices have been employed in attempts to preserve the shoreline and protect lakefront properties. Many of these structures were built by private individuals using any material at hand and in the main have proved to be inadequate. As may be well imagined these structures vary widely in design, nature of construction, degree of protection afforded and cost. It is not possible to enumerate all these types in this report but a few of the more important methods employed are briefly described below.

1. <u>Planting Willow Poles and Installation of Wire Fence Groynes</u>

In 1931 the Natural Process Engineering Company, Waterloo, Ontario, installed the "Schiefele System" of beach protection on some 6,000 feet of beach along the easterly side of Point Pelee. This system of angular willow pole planting consists of placing live willow poles from 30 to 40 feet in length in shallow trenches at 4 foot intervals, and anchoring them in place by means of swan-drag anchors, cross-woven wire netting and sand-bags. The lakeward end of the poles was placed about 60 feet back from the water's edge.

Supplementing this work, wire-mesh groynes were placed at 100-foot intervals along the beach to afford some protection to the willow poles until they had sprouted and become firmly established. These groynes consisted of 30-foot lengths of highway type interlocking wire guard

fencing, 24 inches in width, supported by angle-iron posts securely driven and anchored. The groynes were anchored 10 feet inland from the water's edge and extended 20 feet into the water, pointing a little north of east. Subsequent inspection in 1932 showed that the groynes had not proved effective. In most cases the wire mesh had been knocked down by wave and ice action and the supporting posts were bent over or had disappeared entirely.

> "Along the beach north of the cross-road where the shore was more adapted to this type of protection, this system has shown some success. Although some spot erosion has occurred in this area, the beach has been rebuilt and in 1951 was in excellent condition. However, willow poles planted at the southern end of the point did not prove a success and there is little evidence today of any of the protection work installed some 20 years ago."*

The cost of this work in 1931 was $1.50 per lineal foot of shoreline for the willow pole planting and $1.00 per lineal foot of shoreline for the groyne installations. This method, however, is limited to areas suitable for the rapid growth of willows. Also the poles would have to be planted far enough back from the existing shoreline in order to allow sufficient time for them to become firmly established before being subjected to severe wave action.

2. Oak Piling

Another method of beach protection employed at Point Pelee which was considered to be very successful is shown on Plate No. 31. This design provides for two rows of staggered piles 3 feet apart near the water's edge with piles at 4 foot spacing and another two rows of staggered piles with the same spacing at the vegetation line. At 200 foot intervals a row of traverse piles 4 feet apart are placed as interceptors between the front and back row of piles. The piles are white oak, 14 feet long with a minimum top width of 7 inches and are driven 9 to 10 feet as indicated on the plan.

Apparently this system has proved successful at Point Pelee as the National Parks Branch, Department of

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* Inspection report by National Parks Branch, Department of Resources and Development, Ottawa.

General views of the oak piling protective method, East Beach, Point Pelee. Photographs taken one year after the work was completed indicate that the erosion has been stopped and in one section a good width of beach has been created

Resources and Development, Ottawa, has continued its use during the past 3 years. Here the piling has provided the required protection by building up the beach. The success of this method however, depends upon its ability to trap and hold beach-building material and therefore it is limited to areas where there is a substantial littoral drift. Another disadvantage is that it is unsightly and not suitable where the beach is required for recreational purposes.

The chief advantage of this type of protection is its low cost. In 1950 1,800 lineal feet of beach was protected by this method at a cost of $12.66 per foot of beach or $12.25 per pile in place. Another 1,200 feet of beach was protected by the same method in 1951 at a cost of $13.49 per lineal foot of beach or $12.50 per pile in place. This system was continued during 1952 at practically the same cost.

3. Reinforced Concrete Crosses

A third type of beach protection used along the east side of Point Pelee was reinforced concrete crosses. The first crosses used were 4' x 4' x 8" x 4' in height. Seventy-five in all were installed in two rows and staggered at 25 foot centres. The first row was placed along the water's edge and the second near the line of vegetation. The crosses were cabled together for retrieving purposes in the event of being washed out into the lake. This initial work was successful in building up a beach and preventing further erosion. The cost of this work was $3.52 per foot of frontage or $42.27 per cross in place.

However, it was found that during severe storms some of the crosses were moved out of place and required resetting. It was therefore decided to try heavier crosses. The new type of cross, as shown on Plate No. 32, was 4' x 4' x 10" x 5 feet high and during 1950 and 1951 some 2,800 feet of beach was protected by this method. During the high water of the following year however, many of the

crosses were toppled over and had to be retrieved from the lake and set farther inshore. In this position they have provided a little protection during severe storms, but they are not entirely satisfactory. Moreover, they are hazardous and detract from the appearance of the beach.

The cost, based on 2,800 feet of beach protected, was $2.31 and $3.11 per lineal foot of beach or $30.51 and $37.32 per cross in place for the work done in 1950 and 1951 respectively.

4. Reinforced Concrete Rings

A new type of shore protection currently being experimented with in Ohio is one employing concrete rings or "doughnuts", as shown on Plate No. 33. Reinforced concrete rings, 6 feet in diameter by 2 feet deep and 6 inches thick, are placed in two or three tight rows along the water's edge with the face of the outer row at approximately the 1-foot water depth. According to theory the open rings will trap the sand washed over them by the waves. As the rings become filled, the inner row is lifted and placed out in front and the beach is gradually widened in this manner.

One installation of this type was observed at Fairport Beach, Ohio, but unfortunately it had not been completed. At the time, only a short length of the one row was in place, but a considerable amount of sand had already been trapped in and behind the rings. However, it is too early to say how this method will react under severe storm action. These rings would cost about $13.00 each to make and would probably run about $20.00 apiece in place.

Fairport Beach, Ohio One of the latest experiments in shore protection is this method employing concrete rings

(National Parks Branch, Ottawa)

Reinforced concrete crosses on Point Pelee one month after installation. During 1950 and 1951 about 2,800 linear feet of shoreline was protected by this method. Later during the high water of 1952 many of the crosses were toppled over by the waves and had to be retrieved from the lake.

10

EMERGENCY PROTECTIVE METHODS

Emergency protection, as the name implies, is protection designed to meet a specific condition. It must be susceptible to rapid installation and flexible enough to be readily modified to meet changing conditions. To be effective, it must also be something that the individual property owner can accomplish, preferably according to an over-all plan. Furthermore, being of a temporary nature it must not be expensive.

The difficulty in devising emergency protection to meet the present situation stems from the fact that the high lake levels permit larger waves to impinge on the shoreline, and therefore the protective works must be correspondingly greater. This might require structures of such magnitude that the work would be neither of an emergency nor temporary nature. The cost may increase to an extent greater than could be justified on the emergency basis and the time element become such as to defeat its own purpose. The time element alone would preclude the possibility of any large-scale protective system or the installation of any of the standard shore protective methods such as seawalls, groynes or breakwaters, all of which require careful preliminary studies to determine where each would be effective and desirable.

On the basis of the foregoing, several schemes for providing protection rapidly and at a relatively low cost were devised and briefly tested by the Corps of Engineers, United States Army. These schemes included: (1) a temporary seawall at the base of the bluffs constructed of sand-bags filled with sand or sand and cement; (2) temporary sand-bag seawall with a wire fence in front; (3) temporary

seawall constructed of brush combined with sand-bags to lend stability and weight, and (4) a modified plan of (3) using the wire fence.

The studies indicated that scheme (1) would be effective for waves up to 3 feet in height and that scheme (2) was effective against any height of waves to be expected during summer storms. The use of the wire barrier, as shown on Plate No. 34, would increase the cost of the structure by less than 10 per cent and would be well justified on the basis of decreased maintenance requirements as well as the increased protection afforded.

The use of brush in accordance with schemes (3) and (4) was equally as effective as the all sand-bag wall. Where brush is readily available, its use would probably lower the cost of the finished barrier without any appreciable effect on the time element. The use of the wire barrier with this type of structure had about the same effect on cost, maintenance and effectiveness of the wall as it did on scheme (1). Any wire fencing of a heavy gauge wire with small openings and 4 feet in width would be suitable.

Any of these installations could be accomplished by the individual property owners. With materials available and all owners co-operating, the entire task could be completed within a relatively short time, which is the essence of any emergency work. Subsequent maintenance could also be accomplished by the individual property owners.

The materials required by any of the above schemes are in common use and are readily obtainable at many locations. The sand would be taken from the beach and the brush from the properties immediately adjacent to the shoreline. Where brush is not available within an economic distance one of the other methods would be used. It is probable that cement, sand-bags, wire fencing and perhaps posts would be difficult to obtain in large numbers by individual purchase, but this could easily be overcome by appointing a

central agency, at those locations where their use might be indicated, for the procurement and distribution of these items.

In areas in which stone may be obtained at low cost, quarry run stone should be considered as an alternative to sand-bags. Quarry run stone and other types of rubble have been successfully used in conjunction with the hog wire fencing as emergency protection in some localities. Because of the varying conditions in the shoreline around the lakes, it is probable that the best over-all plan of protection would involve the use of two or more of the above schemes depending upon the availability of materials and the degree of exposure.

The estimated cost per lineal foot of protection for the various plans outlined are tabulated below.

TABLE NO. 23

COSTS FOR EMERGENCY PROTECTION

Scheme	Type	Unit cost per lineal foot*
1	Sand-bags	6.70
2**	Sand-bags and Fence	7.40
3	Sand-bags and Brush	5.30
4**	Sand-bags, Brush and Fence	[illegible].00

* These costs do not include engineering, contingencies or overhead costs.

** Illustrated on Plate No. 34.

The cost of any of the above plans may be substantially reduced by omitting the cement in each case. However, this is not to be recommended, since the cement adds to the weight and life of the structure. The life of a sand-filled bag wall depends upon the life of the bags, whereas the sand-cement mixture will continue to function long after the bags have rotted away.

All of these schemes require considerable maintenance. Maintenance would be required after each storm and

intermittently throughout the ice-free period. It is estimated that the annual cost of maintenance for schemes (1) and (3) would be equivalent to twice the initial cost. On the other hand schemes (2) and (4) would provide a much greater degree of protection and require less maintenance, as the fence tends to hold the structure in place. It is estimated that the annual maintenance cost for these plans would be equivalent to the first costs.

11

INUNDATED AREAS

The shores of the Great Lakes which are subject to inundation vary from agricultural lands to urban communities and industrial centres. In the more highly developed areas many of the houses along the waterfront are so close to the water's edge that seawalls and bulkheads have had to be constructed to protect the buildings from wave action even during low-water stages. Along the north shore of Lake Erie and Lake Ontario there are long narrow beach ridges which have been highly developed with both summer and permanent residences. Some of these beach ridges have water on both sides, while others are backed with low lying farmland. In many cases the ridges are only wide enough for a roadway, or a roadway and one or two rows of houses.

Generally, the housing developments in low areas are only subject to inundation at relatively high lake stages. In a few cases, such as near Point Pelee and Rondeau on Lake Erie, there are rich farmlands, which are actually reclaimed marsh areas, that would be flooded even at moderate lake stages without control works to hold back the water. When the protective structures at these places are overtopped or breached by storms, relatively large areas are flooded to depths of 4 feet or more. The pumping facilities provided for interior drainage are inadequate to cope with such large volumes of water, and several days or even weeks are sometimes required to unwater the areas.

In many areas, particularly the more highly developed ones, there are numerous docks projecting into the water and boat-slips and boat-houses constructed along the shoreline. Such construction, together with seawalls,

bulkheads and other such structures, makes it difficult to provide flood protection. In other areas where housing is constructed along low, narrow beach ridges with water on both sides, it would be necessary to construct a ring of levees or flood walls around the entire area to prevent inundation. Another difficulty in providing protection against inundation is the need for protecting the flood control structures against the force of storm waves off the lakes. The degree of such protection required varies with many factors, including fetch, offshore depths and the width and slope of beach between the structure and the shoreline.

An important factor to consider in connection with providing protection against inundation is that the houses have been built along the water's edge in order to have free and easy access to the water and beach and also to have a clear open view over the water. Construction to the heights required for permanent flood control structures in front of such properties would defeat the very purposes for the selection of the site for a home or summer cottage.

Only a minor amount of permanent works have been constructed to protect against inundation. The areas which have such permanent flood control structures are limited to those which are virtually reclaimed marsh land. The type of construction consists generally of earth dykes with some sections reinforced by means of timber sheet piling bulkhead and groynes. In some places, groynes were placed with a view to aiding in building up and maintaining a protective beach barrier on the lakeward side of the dykes. Areas protected by flood control structures are provided with drainage ditches and pumping facilities to take care of interior drainage and seepage.

During the past few years many small earth dykes and sand-bag barriers have been built to protect housing areas against inundation. This work was accomplished both by individuals and on a co-ordinated basis by communities.

(Windsor Daily Star)

Little has been done in the way of permanent protective works for areas subject to inundation, but many individual property owners are constructing dykes and floodwalls in an effort to protect their homes. Here workmen complete a stone wall at Riverside on Lake St. Clair

In general, the interior drainage and seepage in these areas are taken care of by portable pumps. This temporary work is providing appreciable relief from inundation in many areas but is totally inadequate to insure against flooding during severe storms and extreme high water levels.

Sheltered areas in the lower reaches of tributary streams, in small sheltered coves and bays, can be protected from inundation by conventional methods used for local protection on rivers, except that in the case of earth structures some additional protection will be required from wave action. The determination as to type, that is whether to use impervious earth dykes, steel sheet pile or concrete flood walls, must be determined on the basis of the most economical type to use in each case. Normally, where the base of the structure is at or above low lake elevation and there is sufficient room for dyke construction, this type is the most economical, providing suitable material is conveniently available for such construction. However, where the waterfront is interspersed with docks, bulkheads, boat-slips and other construction, the solid wall type of construction, using steel sheet piles or concrete, may be more feasible. Earth dykes should be protected against erosion from current or wave action by rip-rap.

In order to provide reasonably adequate protection against inundation, the top of the protective structure should be at least two feet above the maximum anticipated water level. In determining the maximum water level consideration must be given to temporary rises which may be superimposed upon the maximum anticipated mean level. Whenever an area is inclosed by a flood control structure, it is necessary to provide pumping facilities to remove interior drainage and seepage water. Detail study is required in each case to determine the amount of pumping capacity required.

Exposed areas as considered herein are those areas which are exposed to direct wave attack from one of the

Great Lakes. The same general principles as for sheltered areas can be followed for providing flood protection, except that more extensive protection is required against wave attack, and higher structures will be required to prevent overtopping. If practicable, a barrier beach should be provided in front of the flood control structure to aid in dissipating the wave energy before the waves strike the structure. The provision and maintenance of such a beach may be encouraged, in some cases, by constructing suitable groyne fields. Sloping stone protection should be used on the lake face, both to protect the structure and to dissipate the wave energy. The stone should have a minimum slope of 3:1 on the lake side and where placed on an earth dyke should be underlain by a properly graded sand, gravel, or crushed stone filter material to prevent the dyke fill from being washed out. As an added precaution, the top of the dyke should be covered with crushed stone to prevent scouring by spray and overtopping waves during severe storms. The size of cover stone required for stability will vary with the exposure of the area to storms off the lake. Stone of from 4 to 5 tons will be required for stability in areas which are exposed to maximum fetches on the lakes.

Pumping facilities will be required for removing interior drainage and seepage. In addition, severe storms may cause some overtopping and spray falling into the area, which may require removal. The capacity of pumping facilities required will have to be determined in each individual case, and no general rule can be established for determining such capacity because of the many variable factors.

Preliminary studies to date on the feasibility of protecting inundated areas from flooding lead to the conclusion that the varied and wide range of conditions encountered are such that no rule of thumb or average or even range of estimates can be made as to a unit cost of providing such protection. In some areas where the waterfront is an important

factor in the utilization or enjoyment of the property, permanent flood control structures are not desired which would have the effect of depreciating the value of the property for the purpose intended. In such cases, temporary emergency measures such as low dykes and sand-bag structures provide appreciable relief from inundation, particularly in sheltered areas. Where there is no objection to permanent flood control structures, detailed engineering and economic analysis is required in each case to determine the feasibility of providing such protection.

Globe and Mail

Located inside Sandusky Bay in Eric County, Ohio, this rubble stone dyke provides satisfactory protection for a low area subject to inundation, but it would not be suitable for exposed lakefront properties. This structure, consisting of a crushed stone core covered with quarry-run stone and a facing of larger stones weighing up to 400 pounds, cost $20 per linear foot

12

THE LONG BRANCH SURVEY

Following the severe storms which did great damage along the shores of Lake Ontario during the winter of 1951, the Council of the Village of Long Branch and a delegation of property owners waited on the Hon. Wm. Griesinger, Minister of Planning and Development, and requested advice and assistance with respect to repairing and preventing in the future, the heavy damage which had been done along the lakefront of that Municipality. As a part of this shoreline is included in the Etobicoke-Mimico Conservation Authority of which the Municipality of Long Branch is a member, the Minister agreed to make a survey of the lakeshore and submit designs with costs for the best and most economical type of structure to give the required protection.

The survey was carried out during the summer of 1951 and the report was presented to the Council of Long Branch on November 1st of the same year. Although the type of structure which was recommended is among the less expensive ones, the cost for protecting such a short distance of shoreline, as will be seen, is nevertheless very expensive, with the result that no action was taken.

*The Village of Long Branch fronting on the north shore of Lake Ontario is one of the series of wholly urbanized communities extending westerly from Toronto. It has a population of 8,500 people. The shoreline along the lakefront extends from the easterly limits of the village at 23rd Street abutting the Town of New Toronto, westerly to the

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* From a report of a survey made by James McLaren and Associates under the direction of the Chief Conservation Engineer, Department of Planning and Development, June to October, 1951.

extreme west limit of the village abutting Toronto Township. The length of shoreline approximates 8,000 feet. With the exception of property owned by the Etobicoke-Mimico Conservation Authority at the mouth of Etobicoke Creek and the several streets that extend to the water's edge, the lake frontage is privately owned, being divided in the main amongst the numerous properties fronting on the south side of Lake Promenade. From the western boundary easterly to the west pier at the mouth of Etobicoke Creek (1300 feet) and easterly beyond the east pier for a length of about 200 feet, property fronting the lake and inland for some distance is very low, the surface in places being only a few inches above high water. Continuing easterly to 23rd Street, the top of the bank along the shoreline is from 6 to 18 feet above water level. The bank is highest and steepest at 38th Street where the surface rises to Elev. 268.0. The material contained in the bank as revealed by the exposed face is typical of the formation of boulder clay, with some silt and sand that is general in the overburden along the lake shore in this vicinity. With the high water levels obtaining when soundings were taken early in July, 1951, (water Elev. 248.75) there was little, if any, margin between the foot of the bank and the water's edge.

The shoreline in Long Branch divides itself into two distinctly different sections, one to the east of the piers at the mouth of Etobicoke Creek and the other to the west. The shore follows a fairly uniform line on a bearing of about North 60 degrees East. Waves during severe storms from the easterly quarter break on the shore obliquely and during such times erosion is most severe. Examination of the shore and observations made on a number of occasions this summer indicate that littoral currents move in the main from east to west.

The shore to the east of Etobicoke Creek, except for about 200 feet, is bordered by an abrupt bank and there is comparatively little evidence of deposits of sand or small shingle along the shoreline.

To the west of Etobicoke Creek the property bordering the shore is low and flat and is in the nature of a sand bar. Apparently the banks to the east are a source of beach-forming materials which are transported westerly by the littoral currents and thrown up on the flat beach by waves. Sand and gravel discharged into the lake by Etobicoke Creek is also transported westerly and this source probably contributes the greater volume of beach-forming material.

The survey showed that a quarried stone revetment along the shoreline from the mouth of the creek easterly to the east limit of the village will provide adequate shore protection in this section at reasonable cost. The revetment should contain not less than 4½ to 5 tons of stone per linear foot of shoreline, with individual blocks weighing not less than 3 tons. The revetment should also contain some smaller stone, to bed in around the base of the lower blocks. The top of the revetment should be as high as Elev. 253.0. Fig. 1, Plate No. 26 shows a typical section of the revetment recommended.

For protection of the stretch of beach to the west of Etobicoke Creek the construction initially of three or four groynes built with large quarried stone blocks such as those described for the revetment in the easterly section, is recommended. Moreover it is expected that such groynes will be effective in aiding the building up of the beach along this part of the shore. The actual placing and design of the groynes is a matter for more consideration. It would appear, however, that the groynes should be about 100 feet in length and contain not less than 400 tons of stone each.

The groynes will serve to provide a measure of protection against immediate erosion and if it is found that they do not promote the building up of a sand and shingle beach, sufficient in itself to dissipate the force of the waves,

a revetment of stone or steel sheet piling along the beach between groynes can be constructed later.

Estimated Cost of Work Recommended

Easterly section, 6600 feet long, from Etobicoke Creek to east limit of village, stone revetment and related work	$440,000.00
Westerly section - stone for groynes supplied and placed (about 1600 tons)	20,000.00
Total: ..	$460,000.00

Before deciding to recommend the use of stone, other types of construction were considered. For example it would be possible by the use of bulkheads to build a wall parallel to the lakeshore some 30 or 40 feet or more away from the base of the bank to restore lakefront property to the approximate line of a number of years ago. The cost of such construction, however, and the necessity of filling in behind would involve expenditures that would greatly exceed the cost of the work here recommended.

With the construction of the revetment in the easterly section as herein recommended, several short groynes can be built to break up littoral currents along the shore, and if it is found that they help to build up the beach they can be readily extended and additional groynes can be built.

In addition to providing adequate protection at the least initial cost, the type of stone revetment and groynes here recommended can be built at any time regardless of the level of water in the lake, season or weather; and is not affected by the difficulties of supply of materials such as is the case nowadays in works where steel and cement are used.

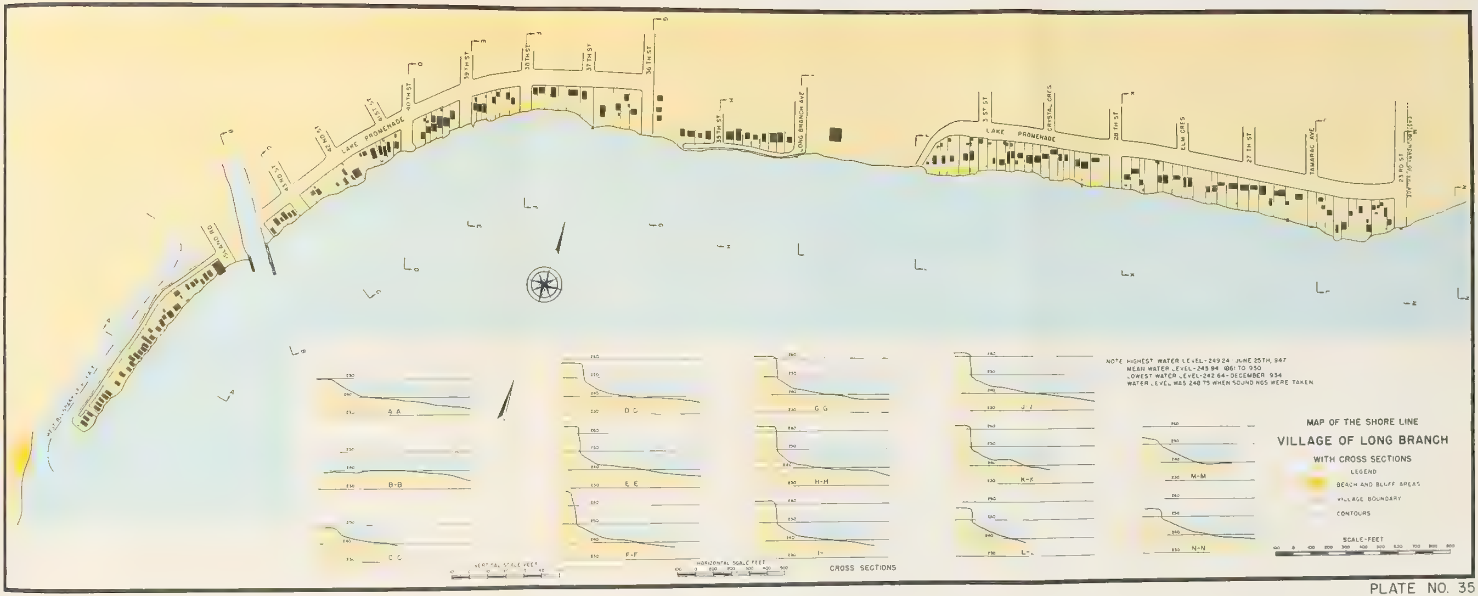
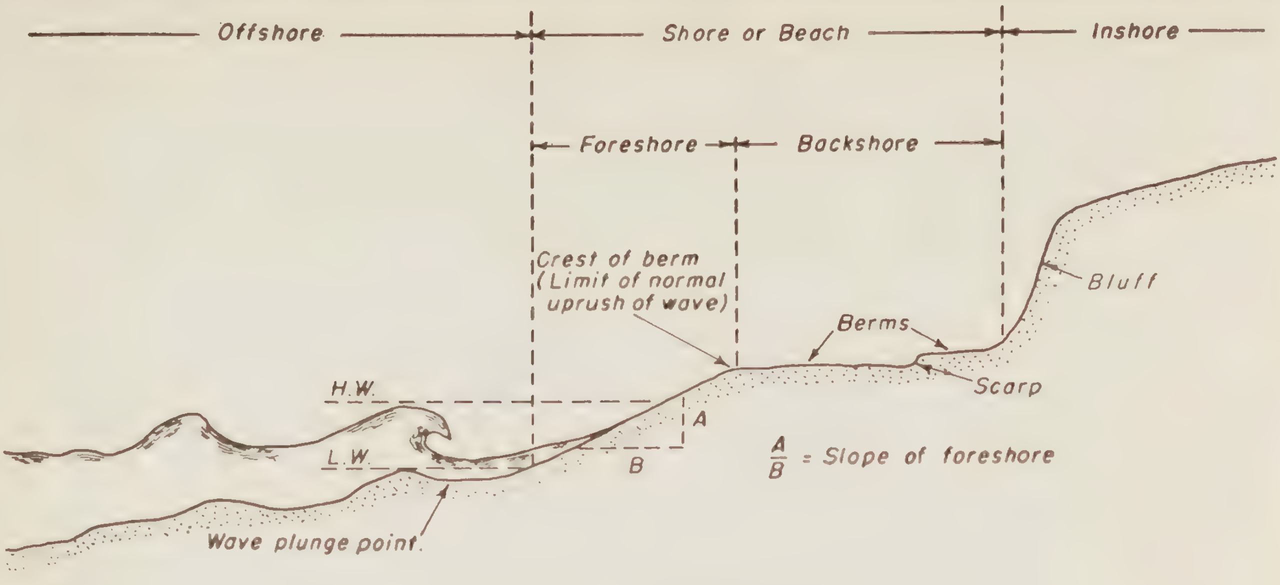

LAKE PROMENADE
ISLAND RD
43 RD ST
42 ND ST
41 ST ST
40 TH ST
39 TH ST
38 TH ST
37 TH ST
36 TH ST
35 TH ST
LONG BRANCH AVE
31 ST ST
CRYSTAL CRES
28 TH ST
ELM CRES
27 TH ST
TAMARAC AVE
23 RD ST
A-A
B-B
C-C
D-D
E-E
F-F
G-G
H-H
J-J
K-K
L-L
M-M
N-N
VERTICAL SCALE FEET
HORIZONTAL SCALE FEET
CROSS SECTIONS
NOTE HIGHEST WATER LEVEL - 249.24 - JUNE 25TH, 947
MEAN WATER LEVEL - 245.94 1861 TO 950
LOWEST WATER LEVEL - 242.64 - DECEMBER 934
WATER LEVEL WAS 248.75 WHEN SOUNDINGS WERE TAKEN
MAP OF THE SHORE LINE
VILLAGE OF LONG BRANCH
WITH CROSS SECTIONS
LEGEND
BEACH AND BLUFF AREAS
VILLAGE BOUNDARY
CONTOURS
SCALE-FEET

PLATE NO. 35



BEACH PROFILE

PLATE NO. 8

GLOSSARY OF TERMS

BACKSHORE. The portion of the shore covered by water during exceptional storms only.

BACKWASH. The flow of water down the foreshore following the uprush.

BERM. The nearly horizontal sand or gravel terrace deposited along the beach under the influence of waves.

BLUFF. The wave erosion feature varying from an inconspicuous slope at the margin of a low shore plain to an escarpment, situated at the lakeward edge of the inshore area.

BODY CURRENTS. The general movement of water from the inlet to the outlet.

CREST OF BERM. The lakeward margin of the berm.

FETCH. The length of water-surface over which the wind from any quarter blows.

FORESHORE. The part of the shore, lying between the crest of the berm and the ordinary low water mark, which is ordinarily traversed by the uprush and backwash of the waves as the water levels rise and fall.

HIGH WATER LINE, LOW WATER LINE, MEAN HIGH WATER LINE, MEAN LOW WATER LINE, and similar terms are defined as the intersections of the planes of the corresponding water levels with the shore.

LEEWARD. When referring to the sand movement, the direction toward which the prevailing littoral drift moves.

LITTORAL CURRENTS. Currents moving parallel to and adjacent to the shoreline.

LITTORAL DRIFT. The material that moves generally parallel to the shoreline under the influence of waves and currents.

MEDIAN DIAMETER. The size of the sieve opening through which 50 per cent of the sand sample by weight passes.

OFFSHORE AREA. The zone that extends indefinitely in a lakeward direction from the low water shoreline.

PLUNGE POINT. The final breaking point of the waves just before the water rushes up on the beach.

SCARP, ESCARPMENT OR BLUFF. An almost perpendicular slope occurring along a shore caused by erosion.

SHORE OR BEACH. The zone extending from the low water mark to the base of the bluff which usually marks the landward limit of effective wave action.

SHORELINE. Refers to low water shoreline when no other designation is given.

SIZE OF SAND. Represented by its median diameter expressed in millimeters (mm).

SLOPE OF FORESHORE. The angle between the tangent to the beach at the high water line and the horizontal.

STILL WATER LEVEL. The level which would be assumed by the surface of the water if wave action ceased.

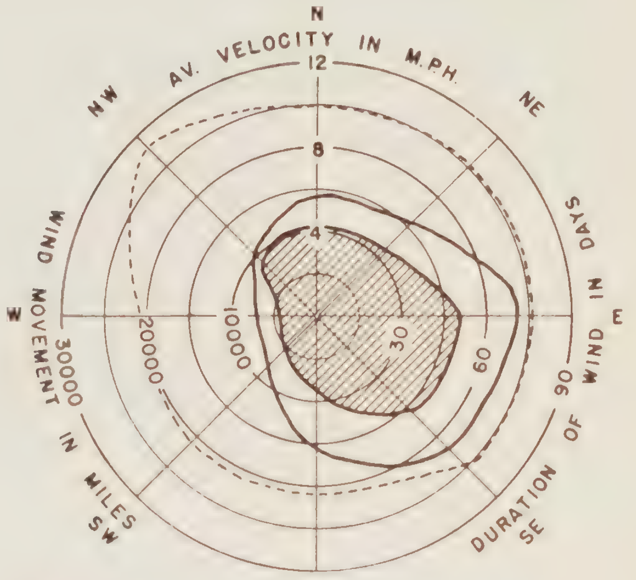
UPRUSH. The rush of the water up the foreshore following the plunge.

WAVE DIRECTION. The orientation of the line of travel of the largest well-defined waves.

WAVE HEIGHT. The vertical distance between the crest and the preceding trough.

WAVE PERIOD. The time interval between the appearance at a fixed point of successive wave crests.

WINDWARD. When referring to the sand movement, the direction from which the prevailing littoral drift moves.

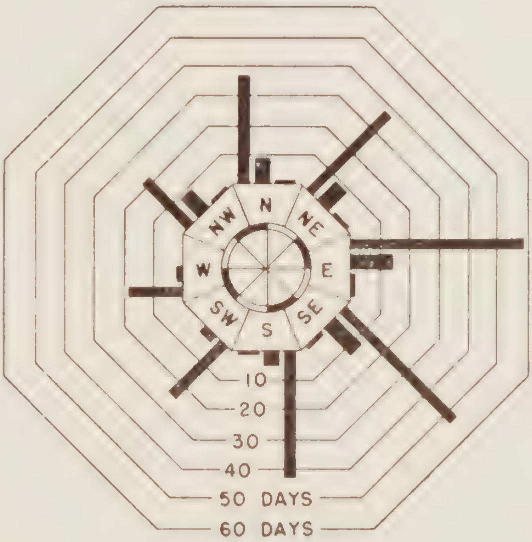


Legend —

AV. VELOCITY IN M.P.H.

DURATION OF WIND IN DAYS

WIND MOVEMENT IN MILES



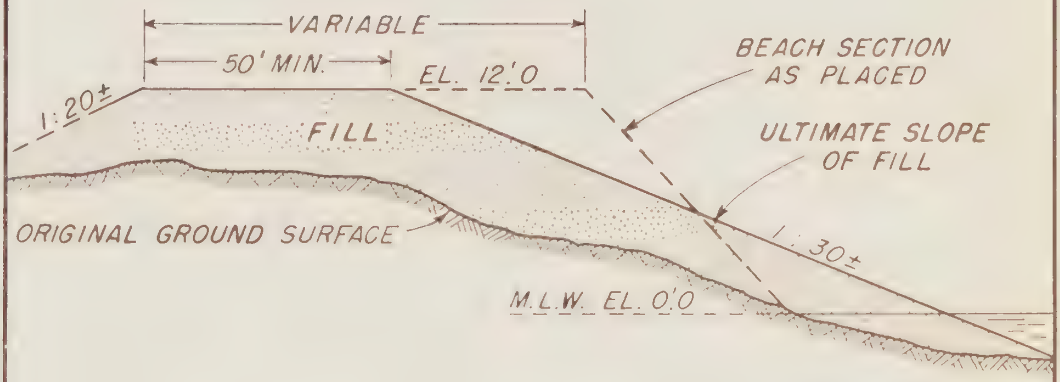
Legend -

VELOCITY RANGE M.P.H.	FORCE BEAUFORT SCALE
0 to 13	0, 1, & 2
Over 13 to 28	3, 4, & 5
Over 28	6 & over

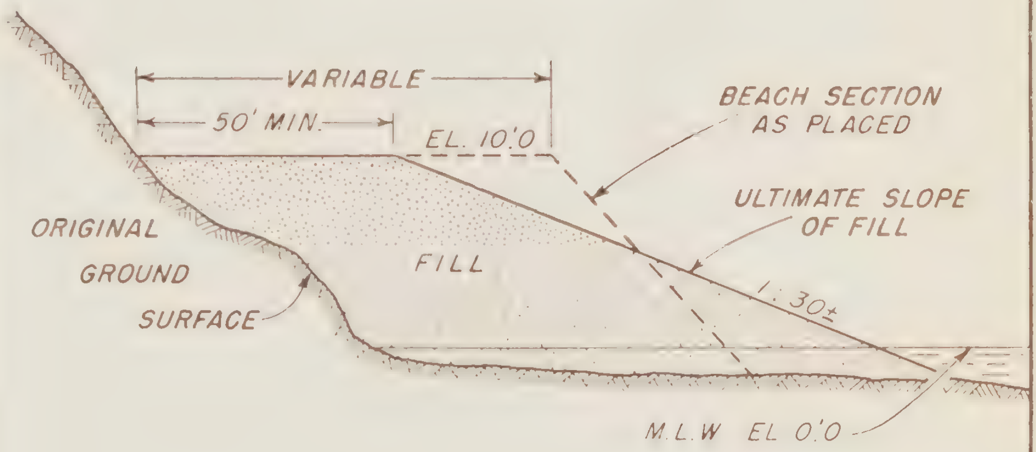
TYPICAL WIND DIAGRAMS

PLATE NO. 9

LOW SHORE AREAS



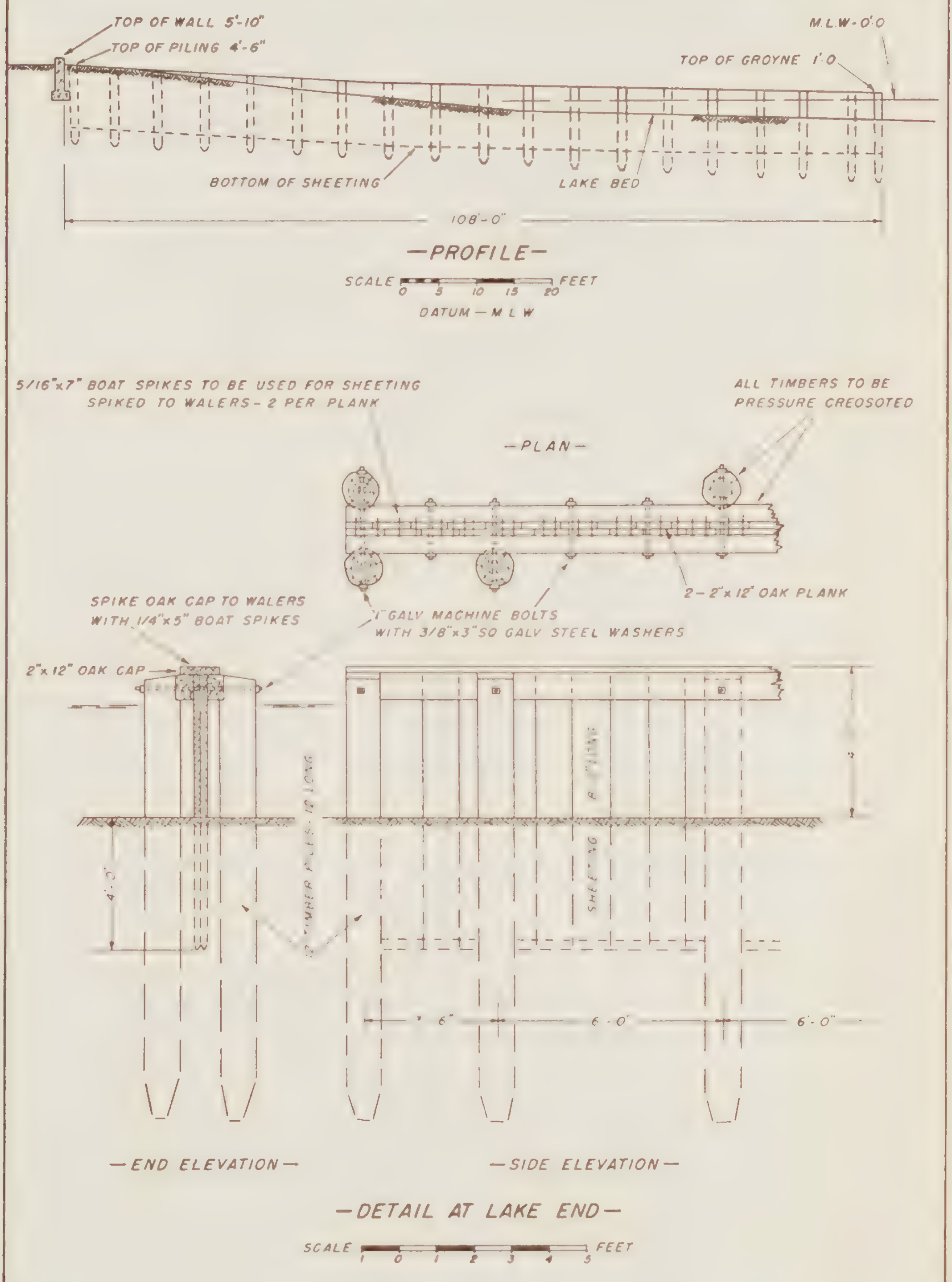
BLUFF AREAS



TYPICAL SECTIONS
BEACH FILL PROTECTION

NOT TO SCALE

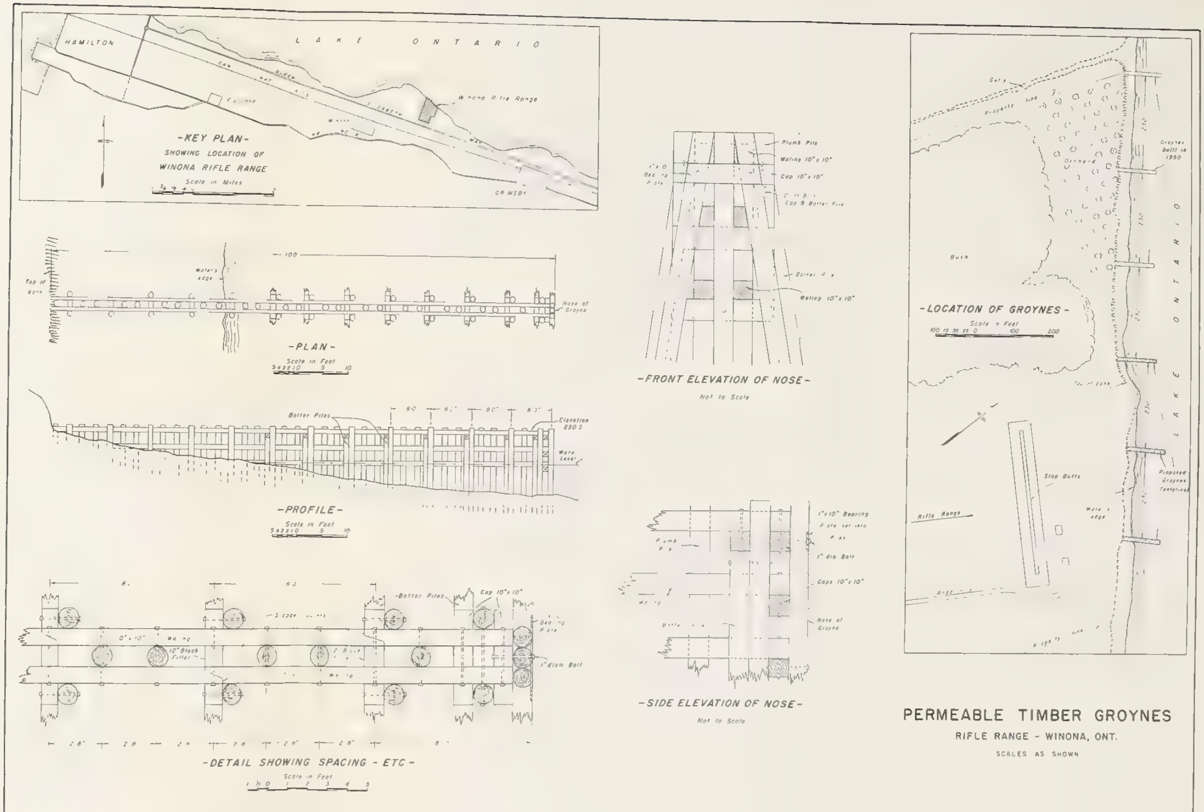
PLATE NO. 10



TYPICAL TIMBER GROYNE

SCALES AS SHOWN

PLATE NO. 11

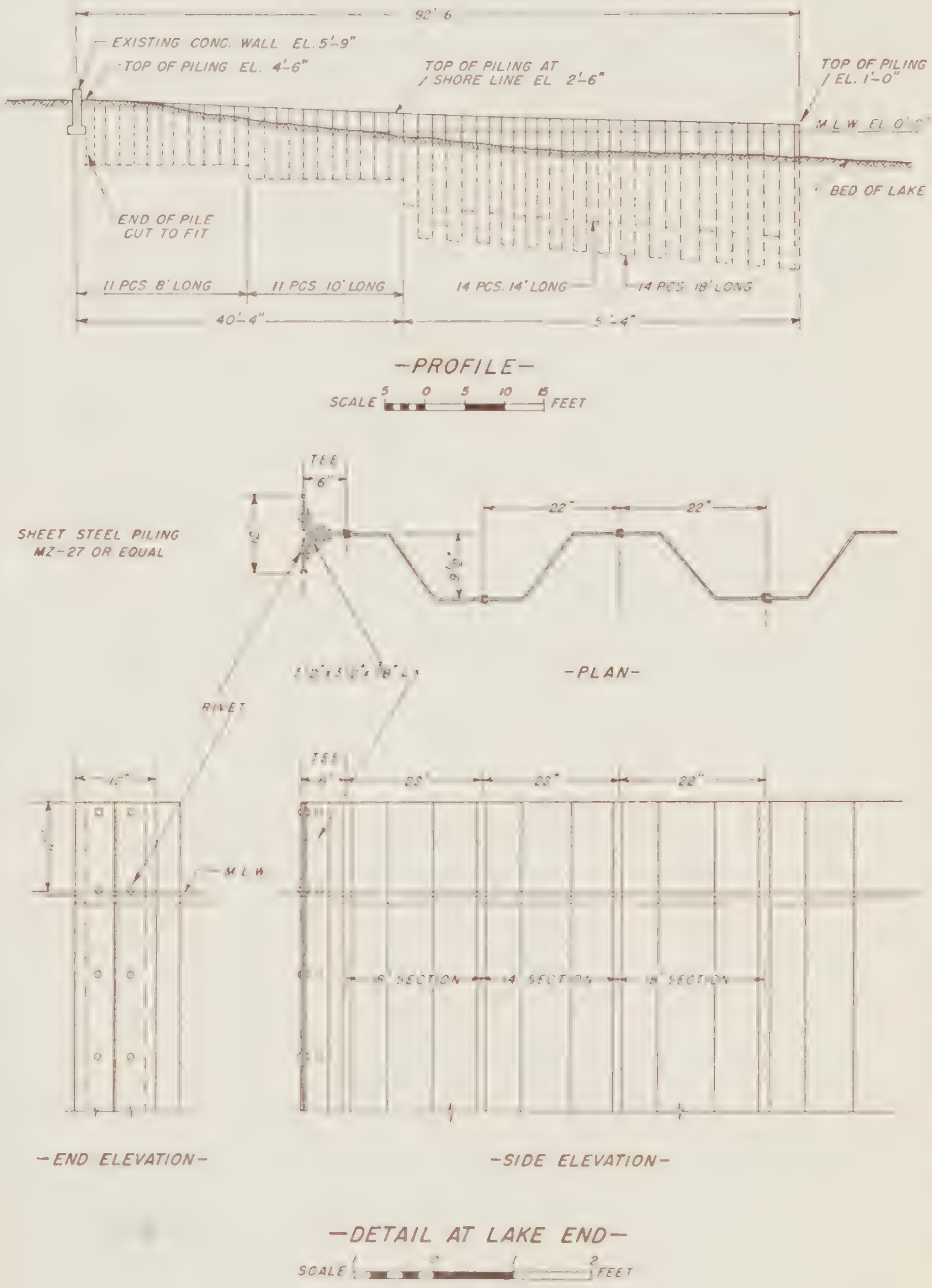


PERMEABLE TIMBER GROYNES

RIFLE RANGE - WINONA, ONT.

SCALES AS SHOWN

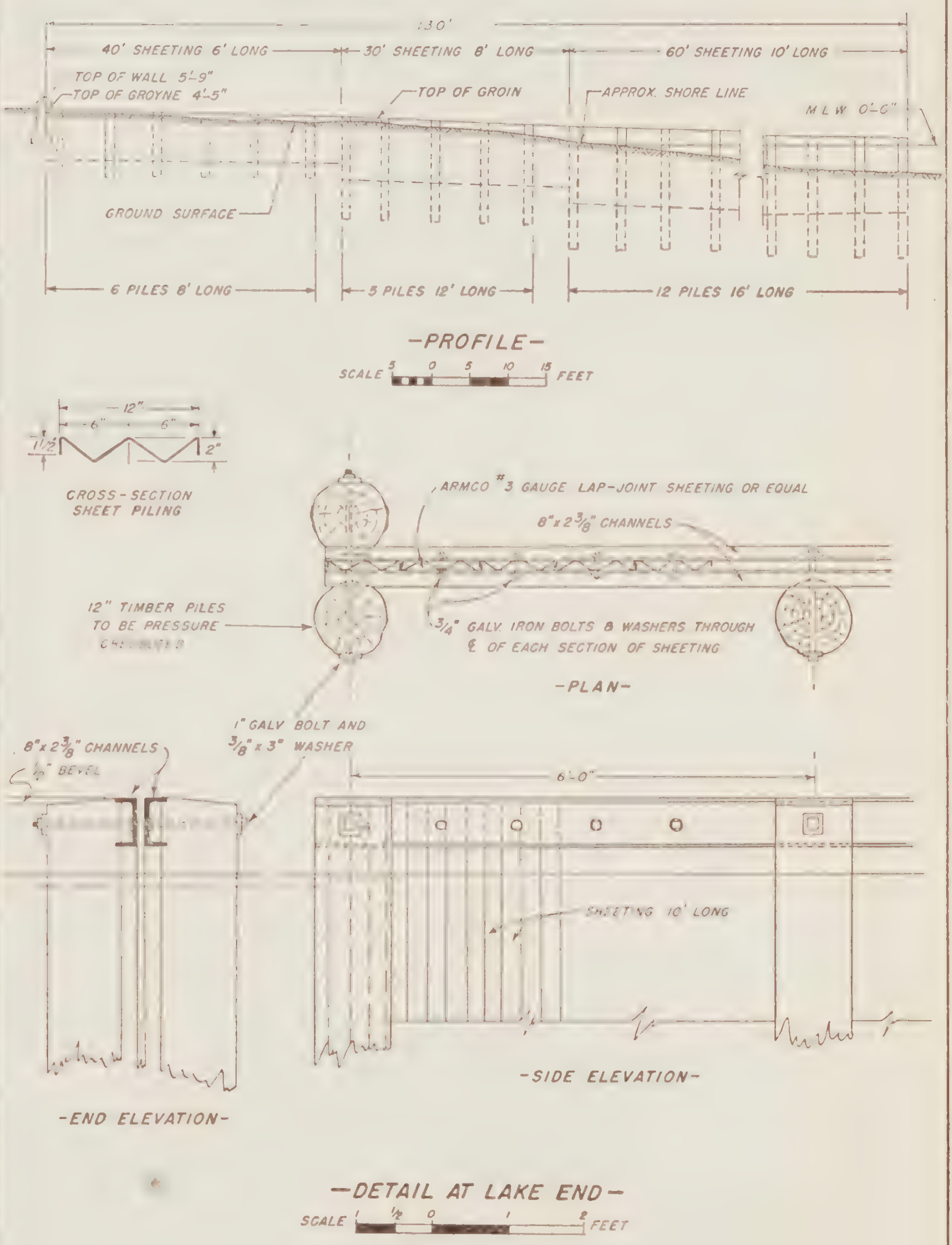
PLATE NO. 12



TYPICAL STEEL SHEET PILING GROYNE

SCALES AS SHOWN

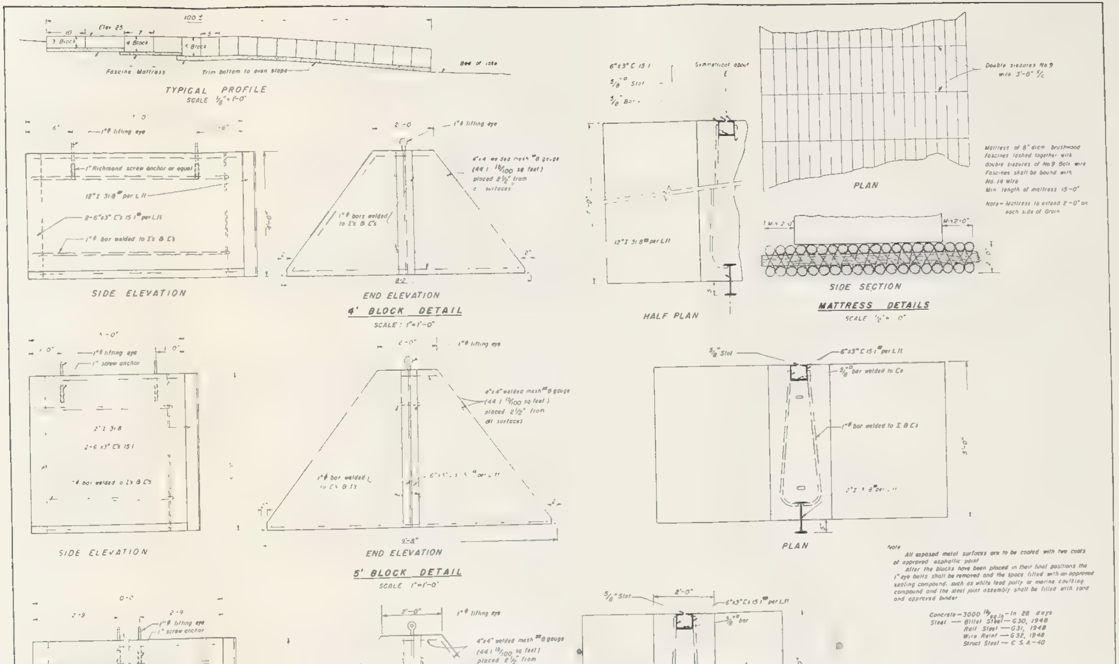
PLATE NO. 13



TYPICAL STEEL & TIMBER GROYNE

SCALES AS SHOWN

PLATE NO. 14



PRECAST CONCRETE GROYNES

EASTERN BEACHES — TORONTO

PLAN SHOWING TYPICAL PROFILE, BLOCK AND FASCINE MATTRESS DETAILS

SCALE — AS SHOWN

PLATE NO. 15

— PROFILE —

SCALE 5 3 0 5 10 FEET

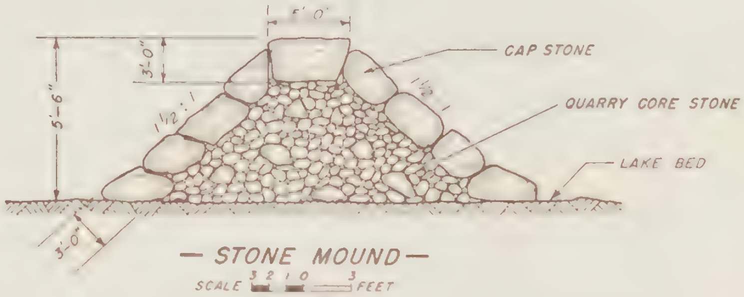


Fig. 1

— STONE MOUND —

SCALE 3 2 1 0 3 FEET

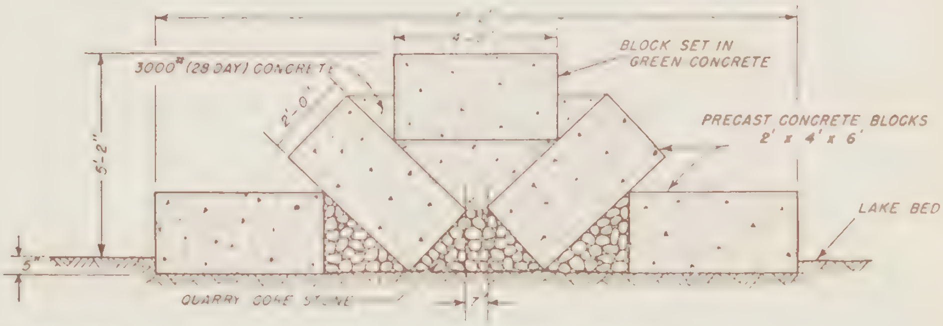


Fig. 2

— PRECAST CONCRETE BLOCK —

SCALE 2 1 0 3 FEET

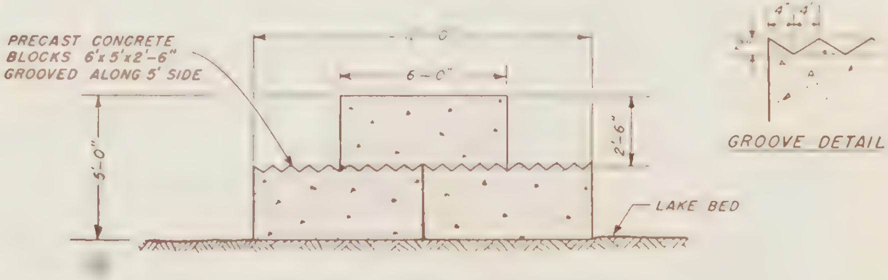


Fig. 3

— PRECAST CONCRETE BLOCK —

SCALE 3 2 1 0 3 FEET

PROFILE AND SECTION

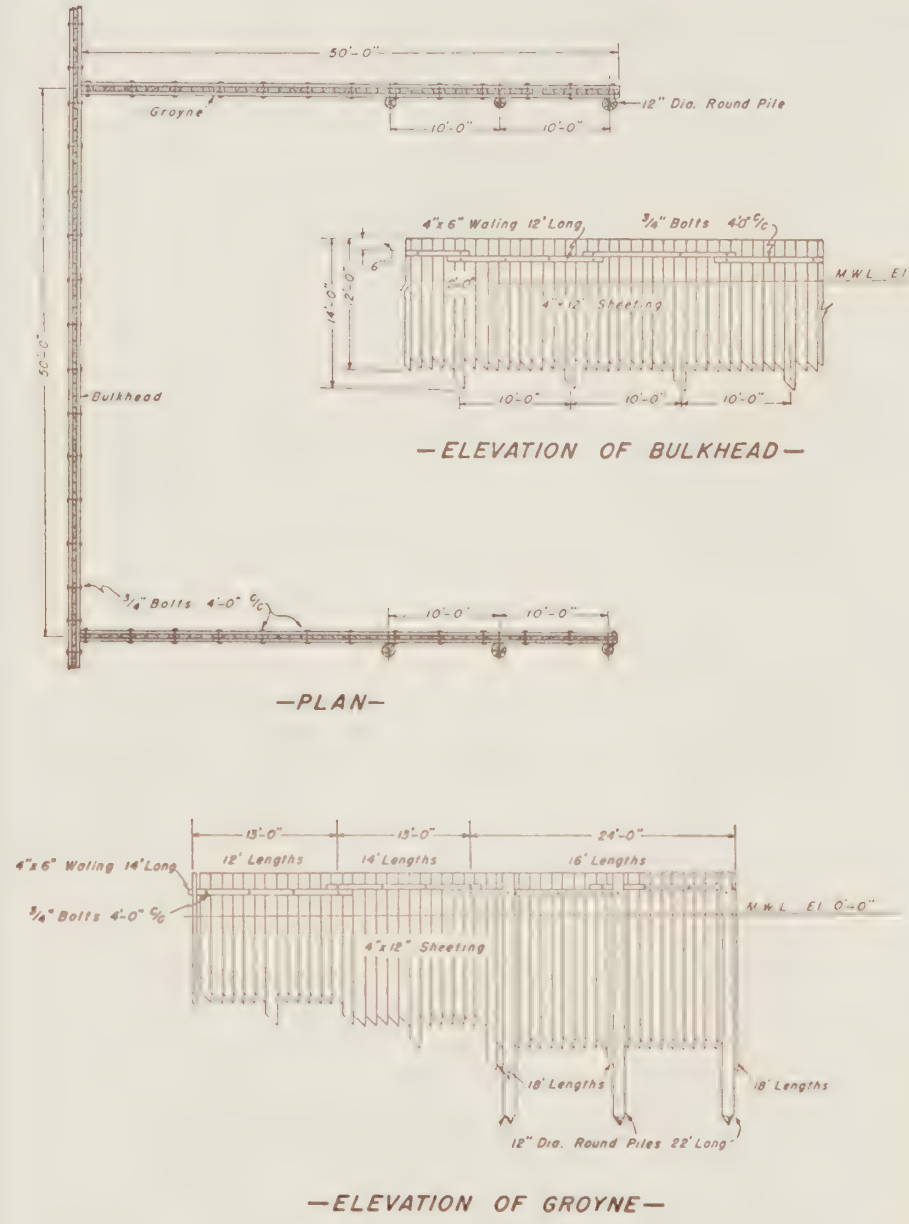
TYPICAL STONE GROYNE

WITH ALTERNATIVE

PRECAST CONCRETE BLOCK SECTIONS

SCALES : AS SHOWN

PLATE NO. 16

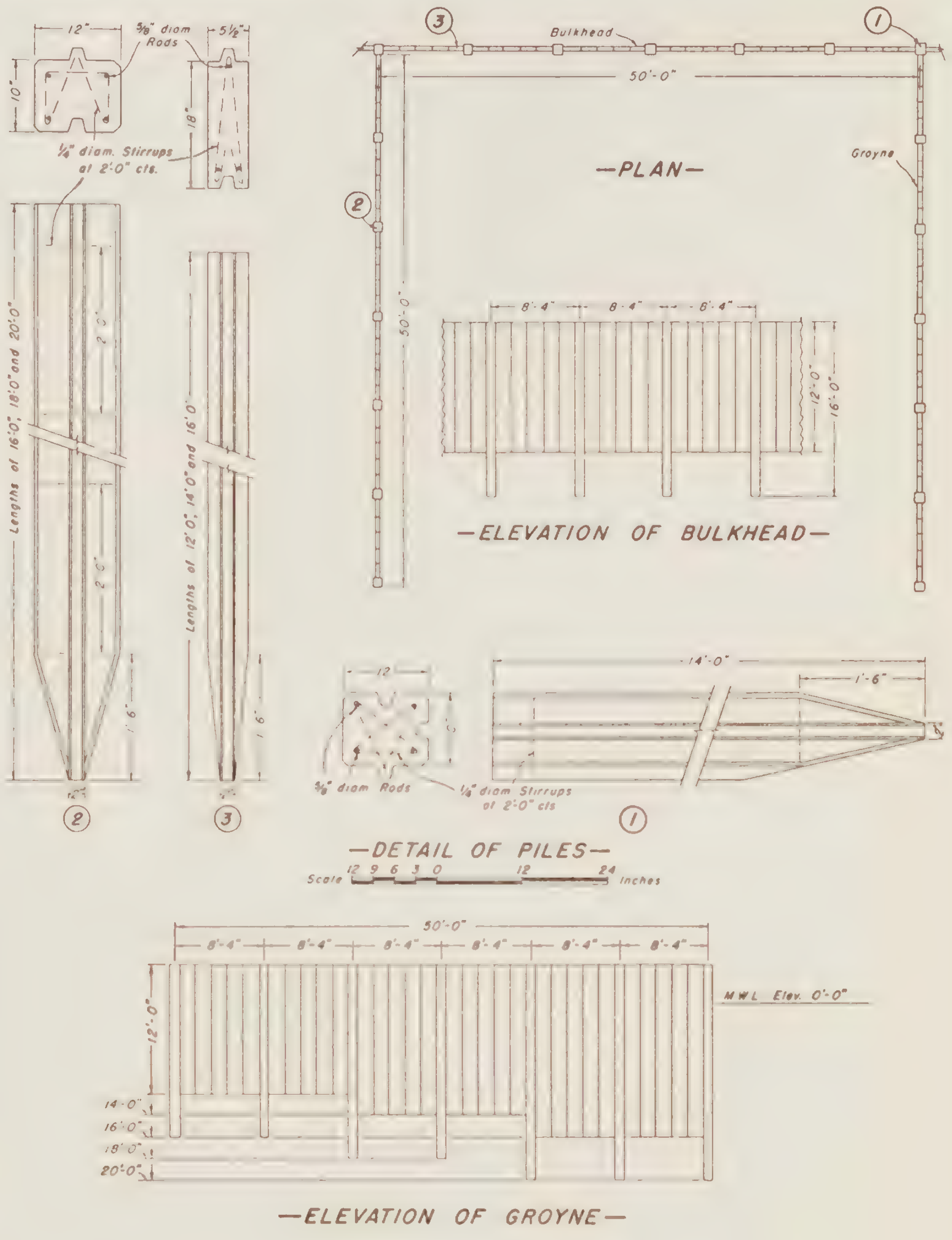


TIMBER BULKHEAD AND GROYNE

SCALE OF FEET

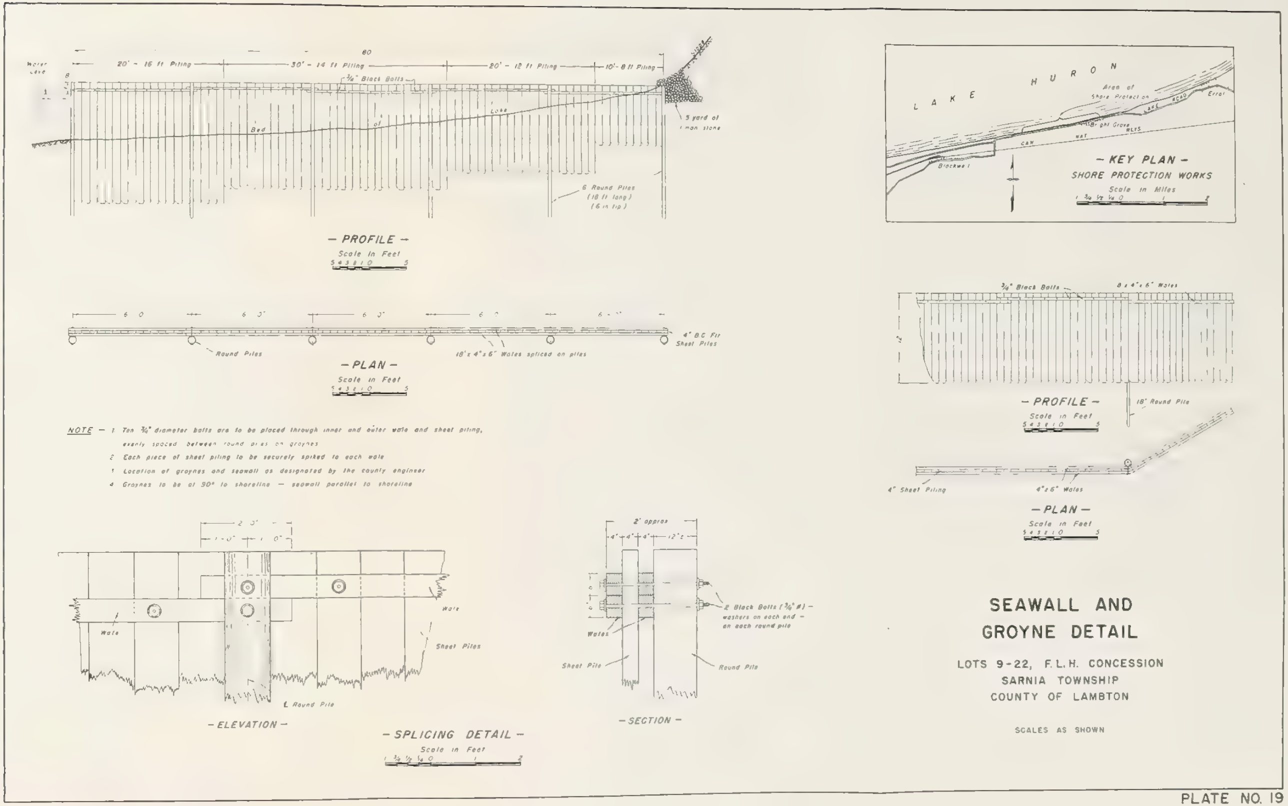
10 0 5 10 15 20

PLATE NO. 17



CONCRETE BULKHEAD AND GROYNES

SCALE : FEET



20' – 16 ft Piling
30' – 14 ft Piling
20' – 12 ft Piling
10' – 8 ft Piling
3/4" Black Bolts
Bed of Lake
5 yard of
6 Round Piles
(18 ft long)
(6 in tip)
– PROFILE –
Scale in Feet
Round Piles
18' x 4" x 6" Wales spliced on piles
4" B.C. Fir
Sheet Piles
– PLAN –
Scale in Feet
NOTE – 1. Ten 3/4" diameter bolts are to be placed through inner and outer wale and sheet piling, evenly spaced between round piles on groynes
2. Each piece of sheet piling to be securely spiked to each wale
3. Location of groynes and seawall as designated by the county engineer
4. Groynes to be at 90° to shoreline — seawall parallel to shoreline
Wale
Sheet Piles
Round Pile
– ELEVATION –
– SPLICING DETAIL –
Scale in Feet
2' approx
2 Black Bolts (3/4" ø) – washers on each end – on each round pile
Wales
Sheet Pile
Round Pile
– SECTION –
L A K E H U R O N
Area of Shore Protection
Bright Grove
Blackwell
– KEY PLAN –
SHORE PROTECTION WORKS
Scale in Miles
3/4" Black Bolts
8 x 4" x 6" Wales
– PROFILE –
18' Round Pile
Scale in Feet
4" Sheet Piling
4" x 6" Wales
– PLAN –
Scale in Feet
SEAWALL AND
GROYNE DETAIL
LOTS 9-22, F.L.H. CONCESSION
SARNIA TOWNSHIP
COUNTY OF LAMBTON
SCALES AS SHOWN

PLATE NO. 19

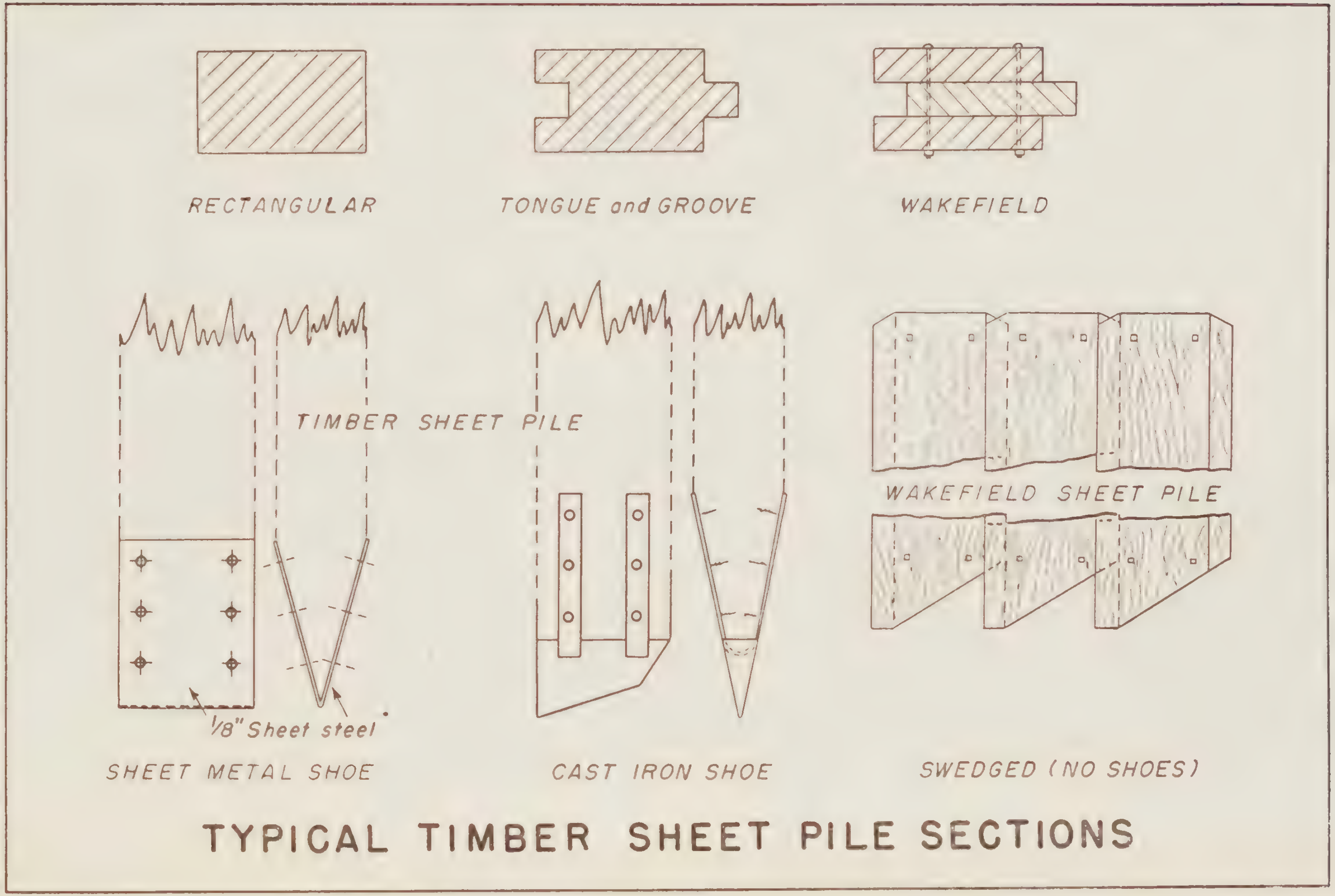
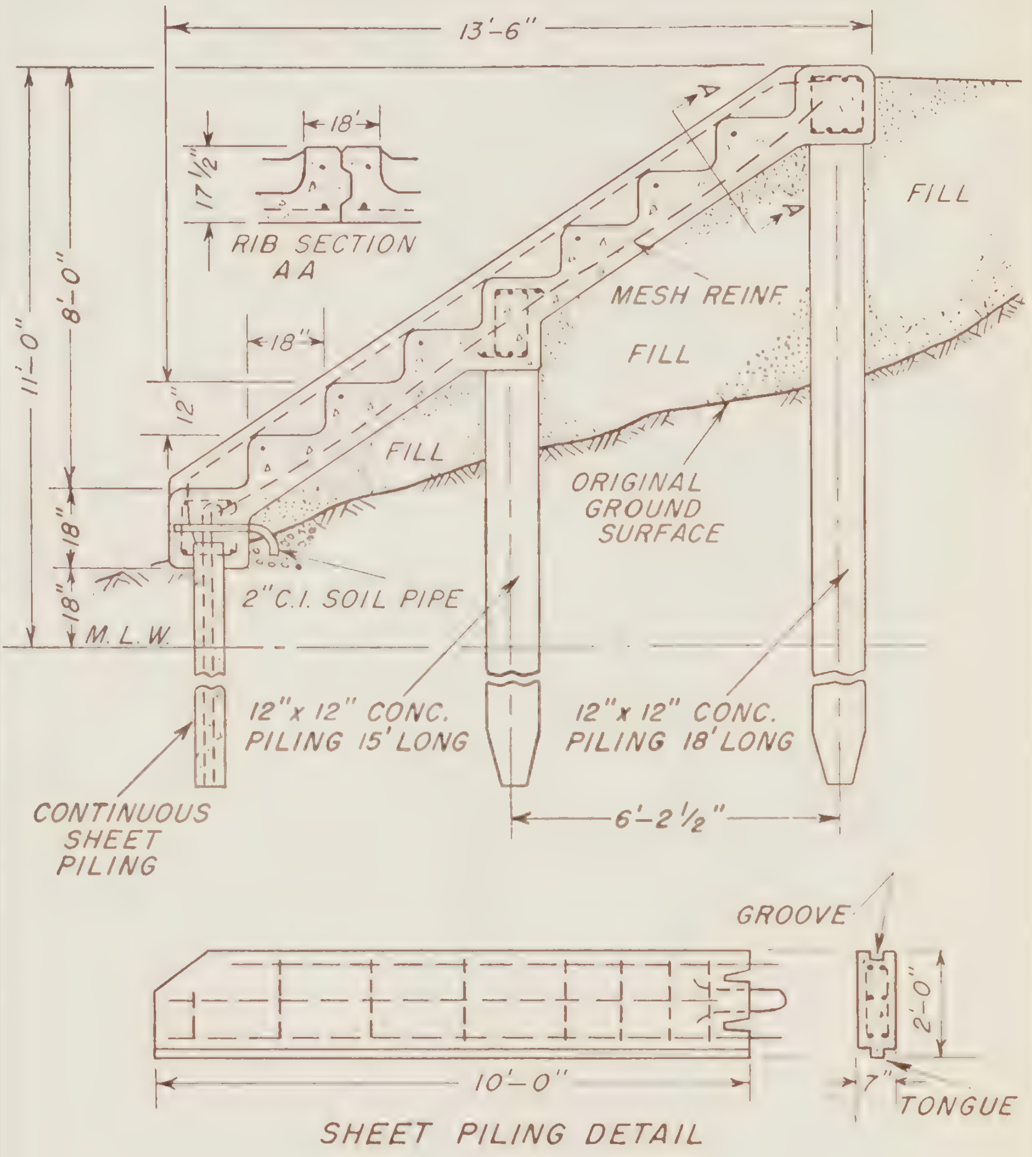

RECTANGULAR
TONGUE and GROOVE
WAKEFIELD
TIMBER SHEET PILE
WAKEFIELD SHEET PILE
1/8" Sheet steel
SHEET METAL SHOE
CAST IRON SHOE
SWEDGED (NO SHOES)
TYPICAL TIMBER SHEET PILE SECTIONS

PLATE NO. 20

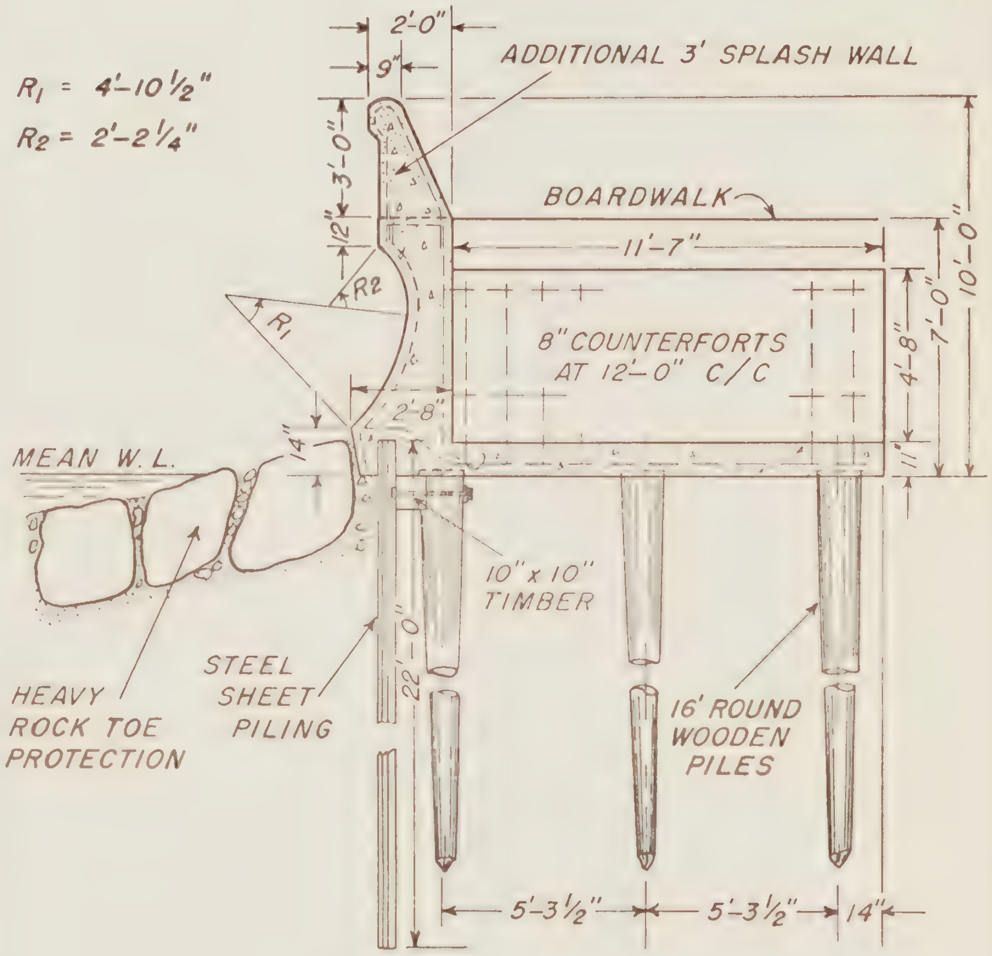


TYPICAL SECTION

STEPPED-FACE SEA WALL

SCALE 3 2 1 0 1½ 3 FEET

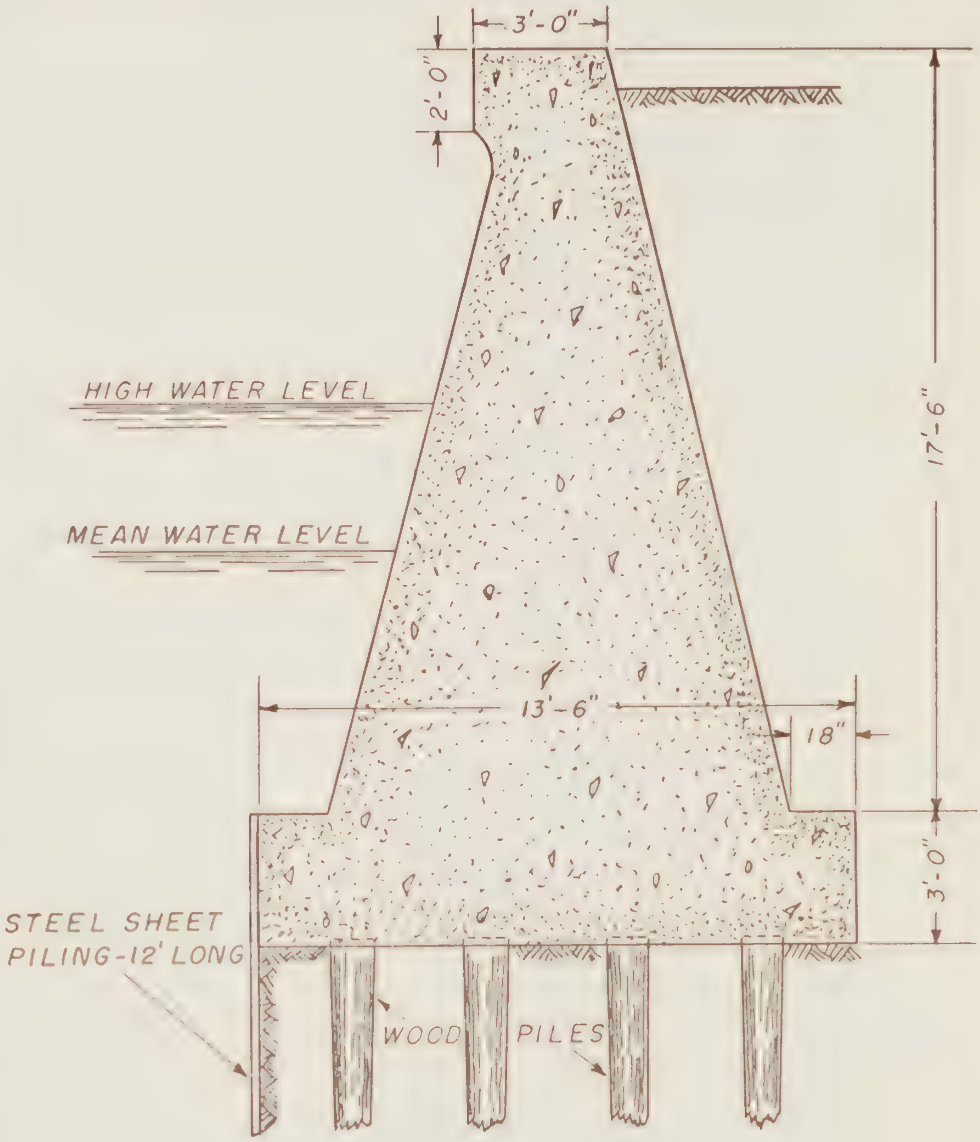
PLATE NO. 21



TYPICAL SECTION

CURVED-FACE SEA WALL

PLATE NO. 22

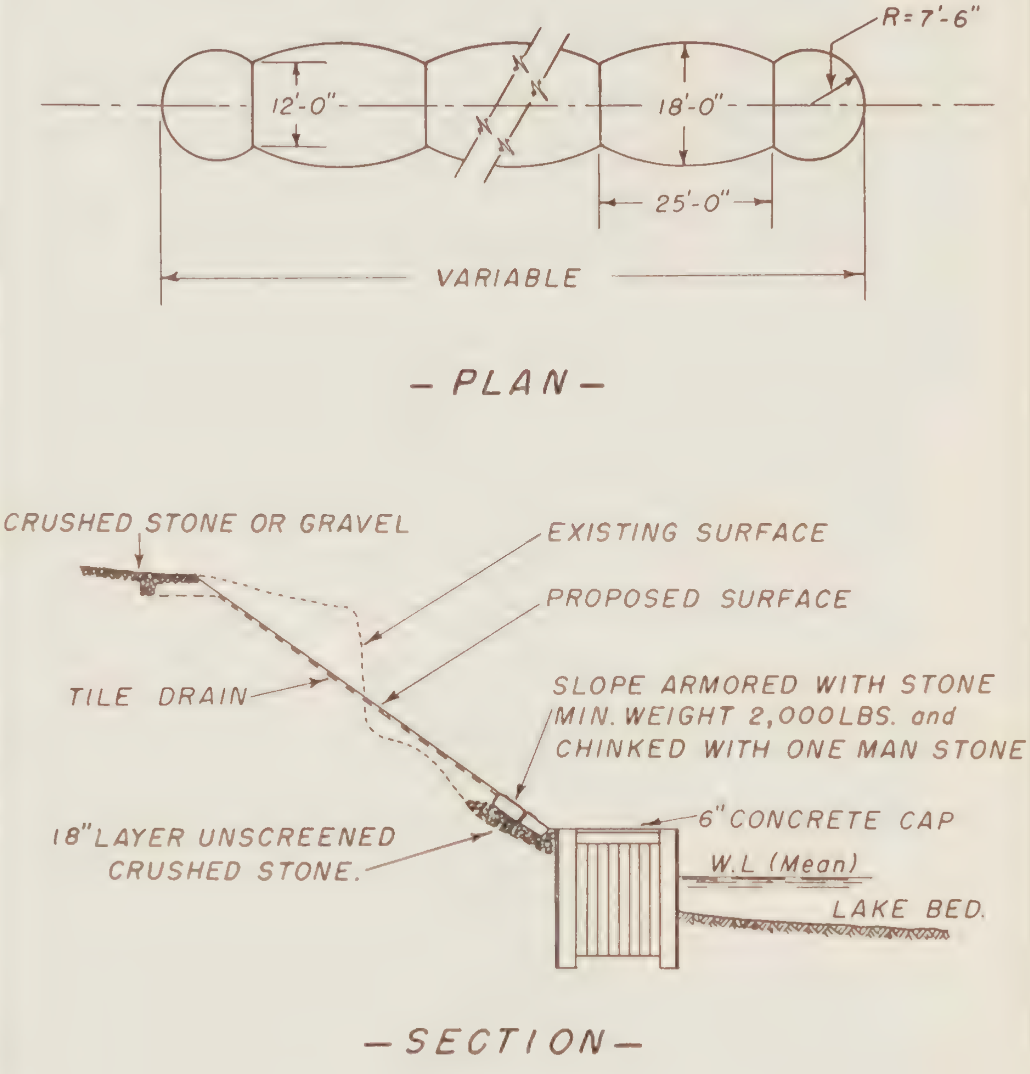


TYPICAL SECTION

VERTICAL FACE SEAWALL

SCALE 2 1 0 1 2 3 4 5 6 FEET

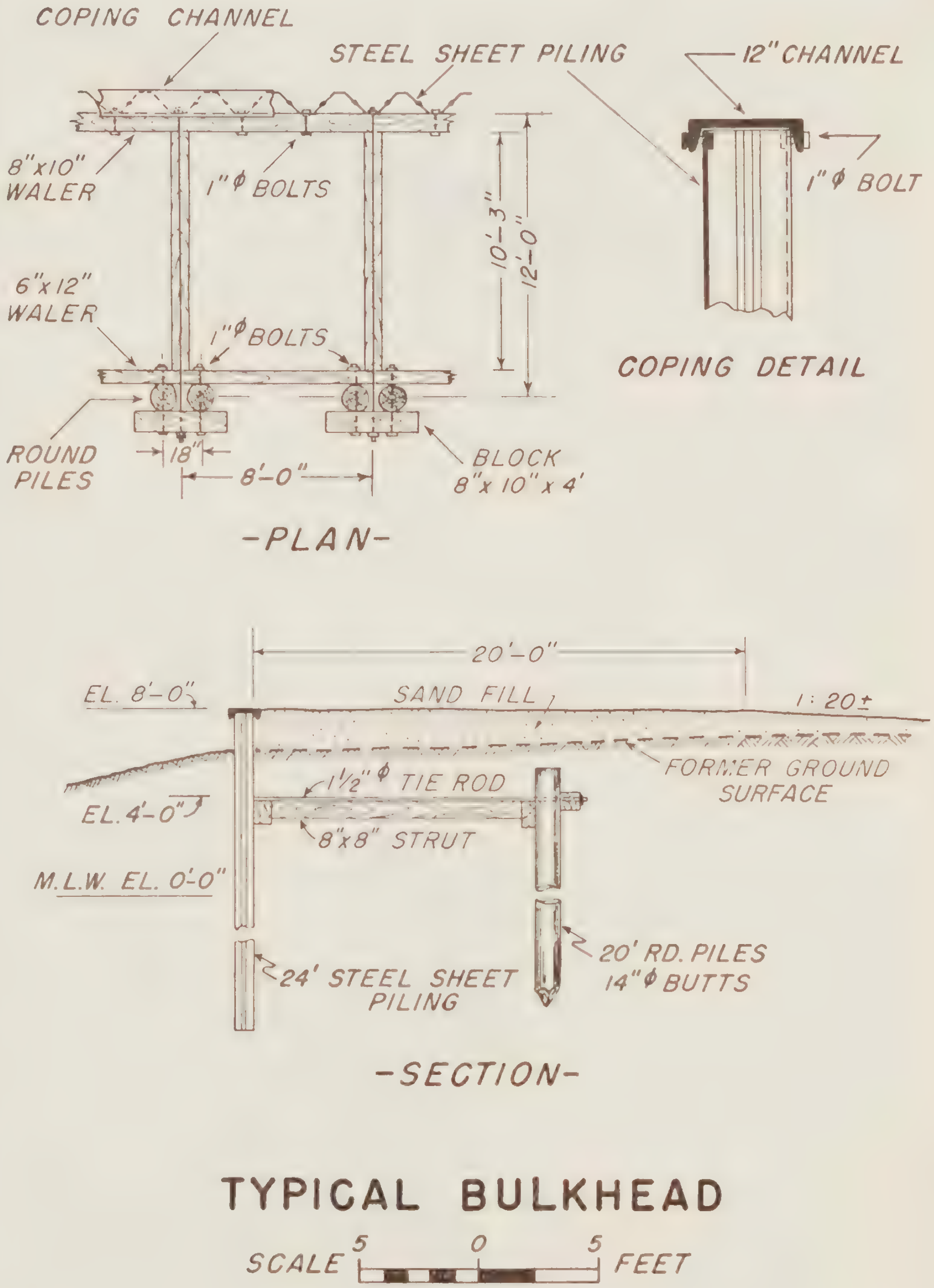
PLATE NO. 23



CELLULAR STEEL

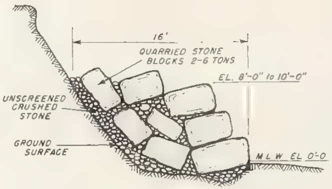
SHEET PILE SEA WALL

PLATE NO. 24



TYPICAL BULKHEAD

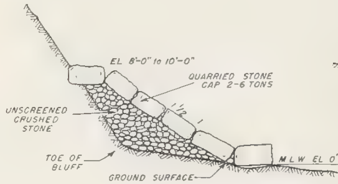
PLATE NO. 25



QUARRIED STONE REVETMENT

SCALE 3 2 1 0 2 4 6 FEET

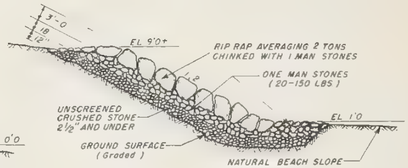
FIG. 1



CAPPED RIP RAP

SCALE 3 2 1 0 2 4 6 FEET

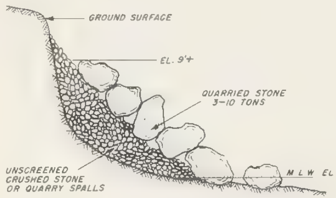
FIG. 2



PLACED RIP RAP

SCALE 3 2 1 0 2 4 6 FEET

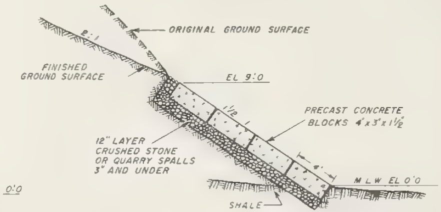
FIG. 3



RANDOM DUMPED RIP RAP

SCALE 3 2 1 0 2 4 6 FEET

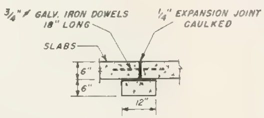
FIG. 4



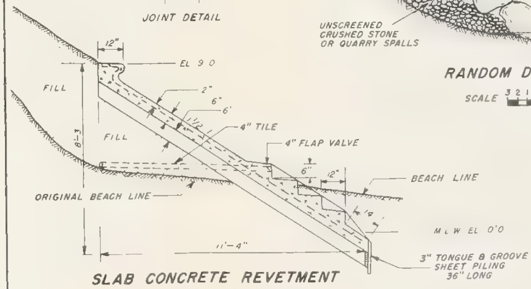
CONCRETE BLOCK REVETMENT

SCALE 4 3 2 1 0 2 4 6 FEET

FIG. 5



JOINT DETAIL



SLAB CONCRETE REVETMENT

SCALE 2 1 0 2 4 FEET

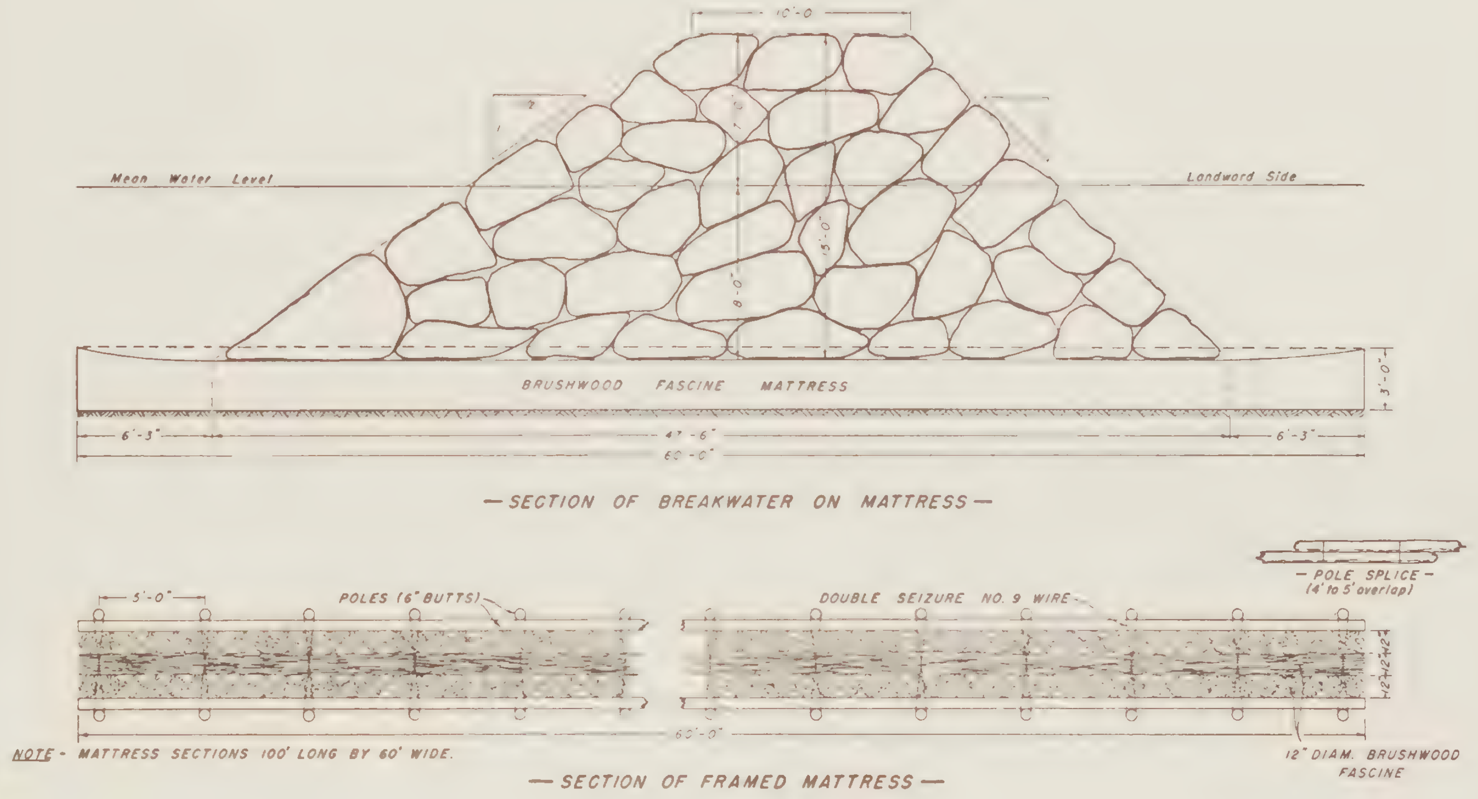
FIG. 6

SHORE PROTECTION

TYPICAL REVETMENT SECTIONS

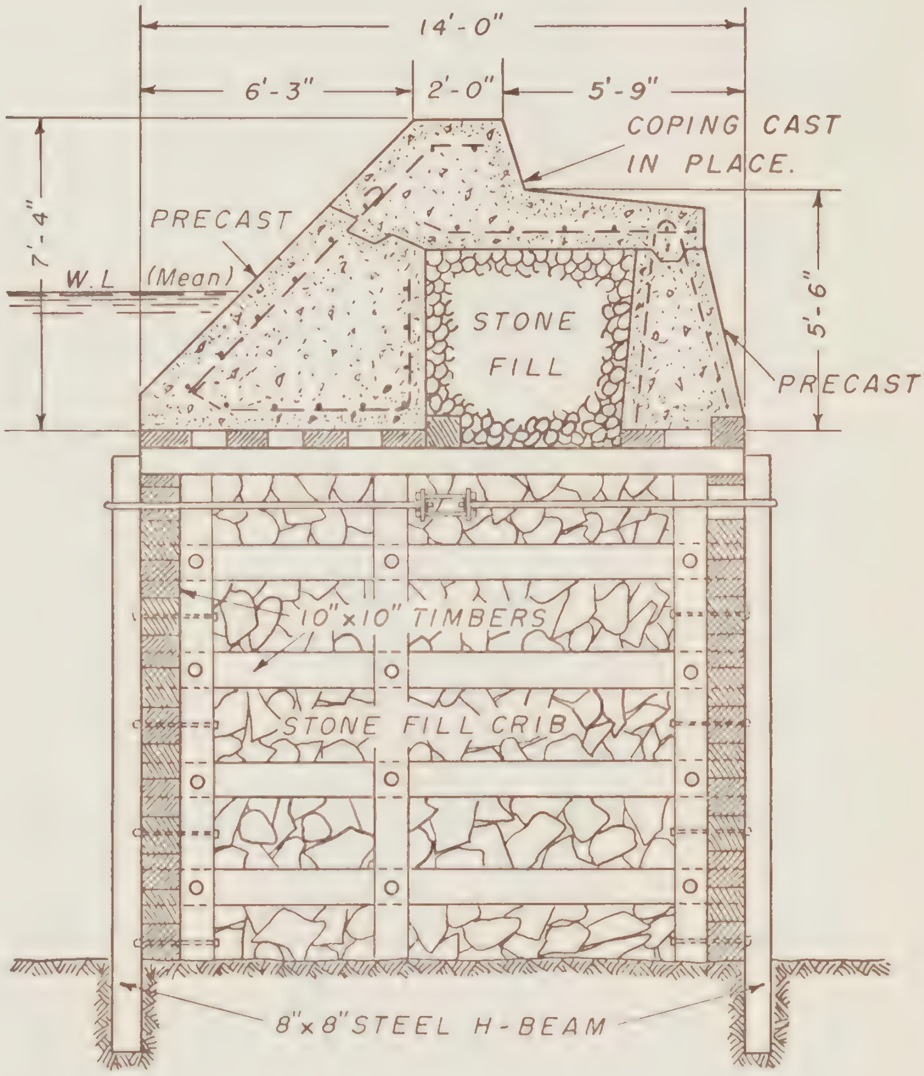
SCALES AS SHOWN

PLATE NO. 26



RUBBLE MOUND BREAKWATER

PLATE NO. 27

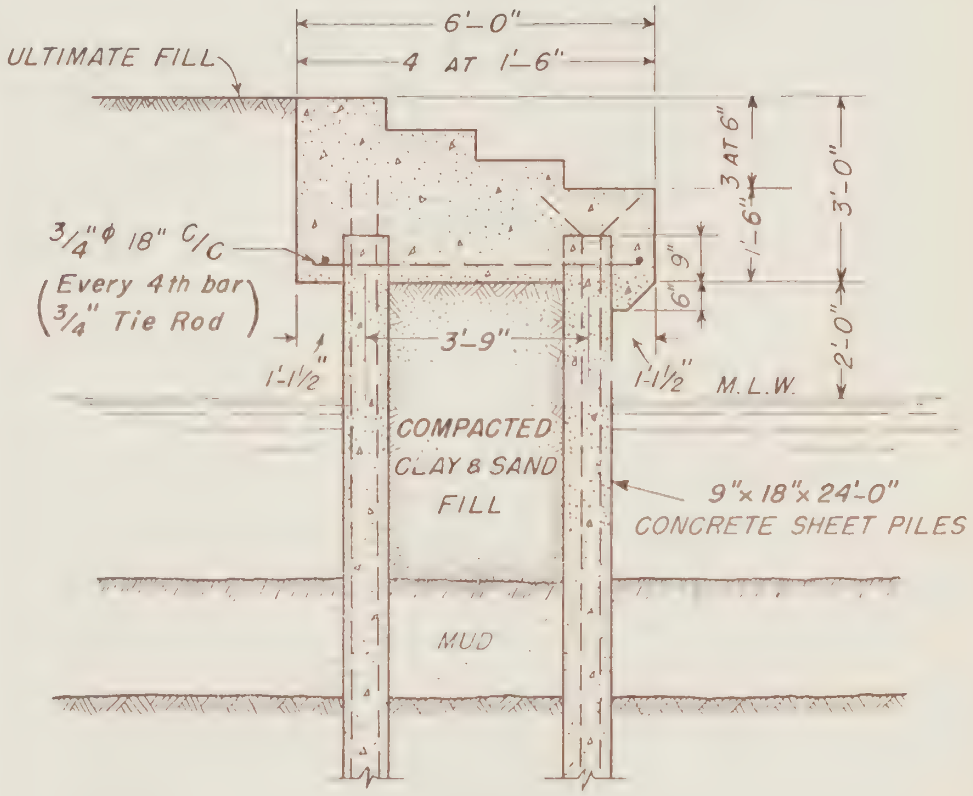


TYPICAL SECTION

CONCRETE and TIMBER BREAKWATER

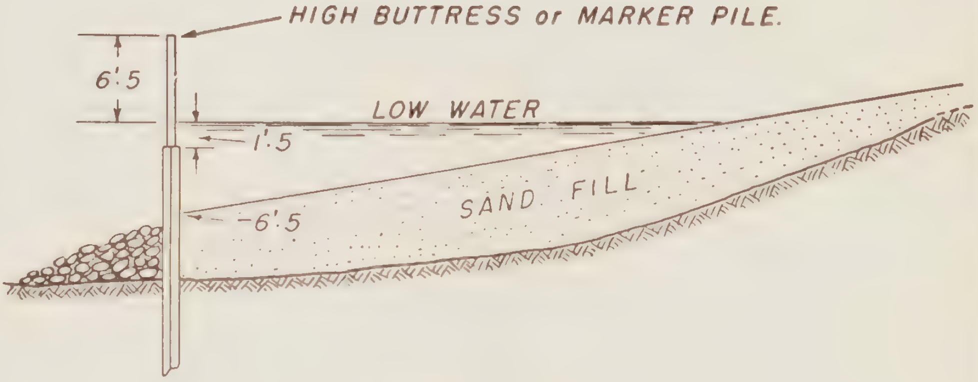
SCALE 2 1 0 1 2 3 4 5 6 FEET

PLATE NO. 28

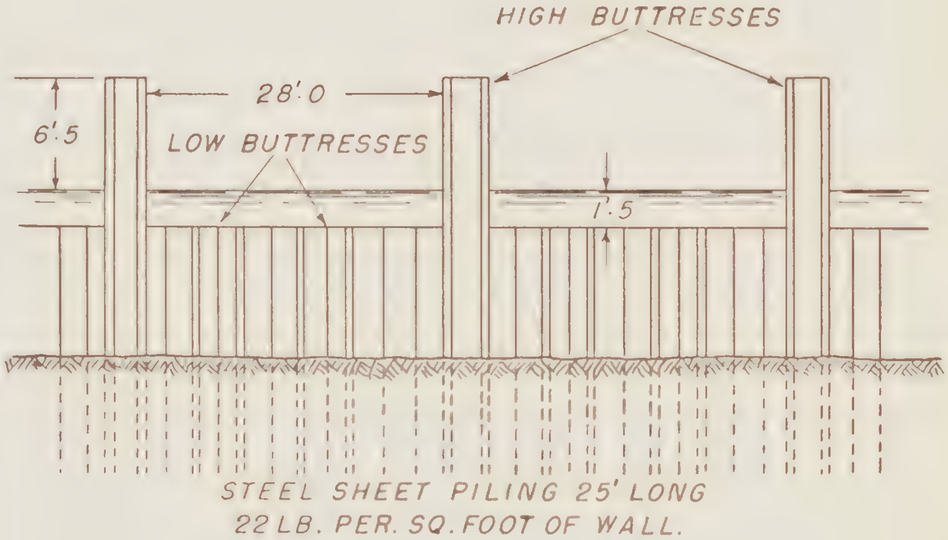


CONCRETE PILE BREAKWATER
AND FUTURE BULKHEAD

PLATE NO. 29



- PROFILE -

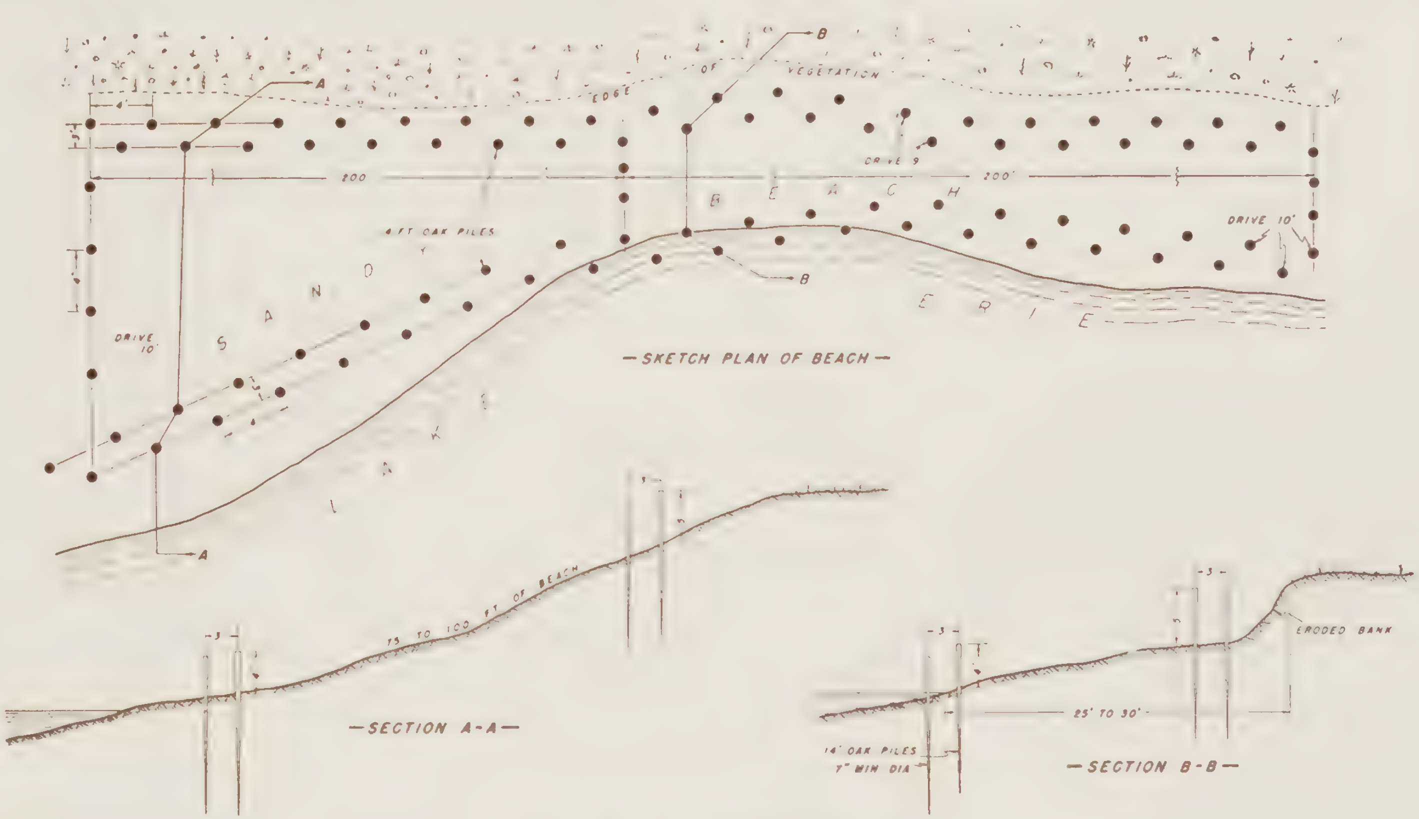


- ELEVATION -

SUBMERGED BREAKWATER

NOT TO SCALE

PLATE NO. 30



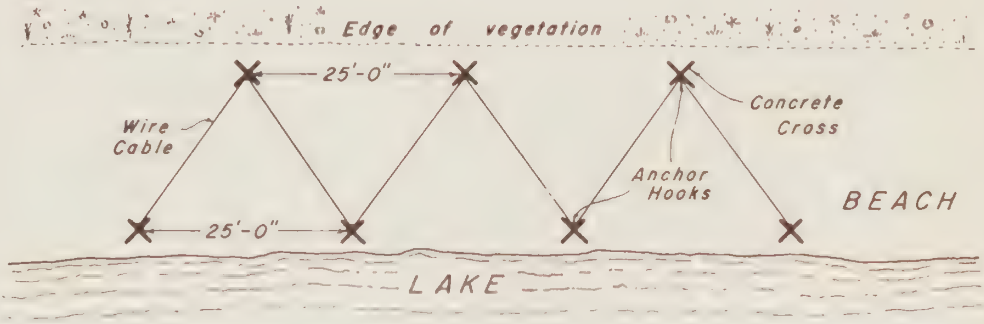
OAK PILING CONSTRUCTION

SKETCH PLAN SHOWING METHOD OF BEACH PROTECTION WORKS

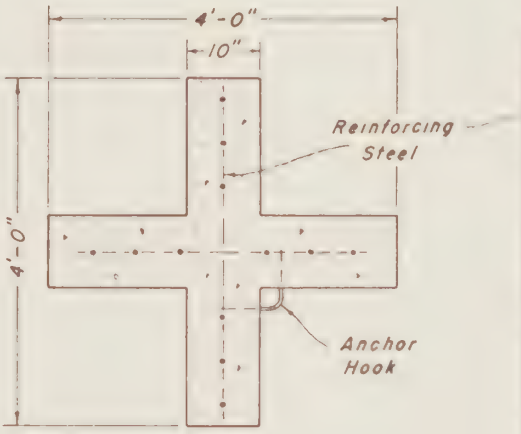
EAST BEACH - POINT PELEE NATIONAL PARK, ONTARIO

NOT TO SCALE

PLATE NO. 31



—SKETCH PLAN OF CROSS INSTALLATION—



—PLAN—

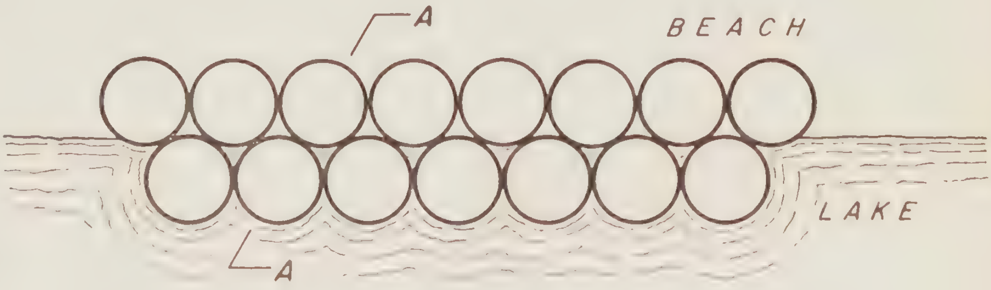
—ELEVATION—

DETAIL OF

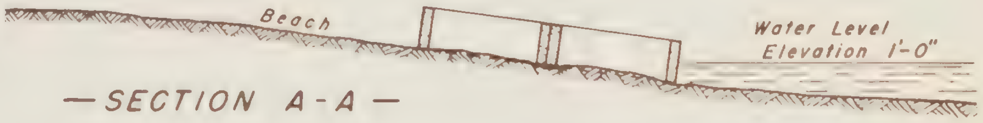
REINFORCED CONCRETE CROSS

FOR POINT PELEE BEACH PROTECTION

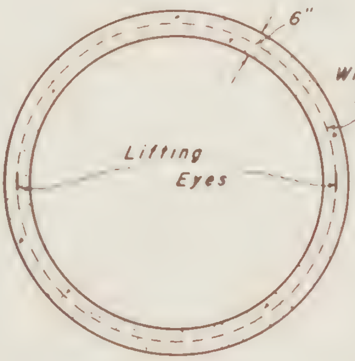
PLATE NO. 32

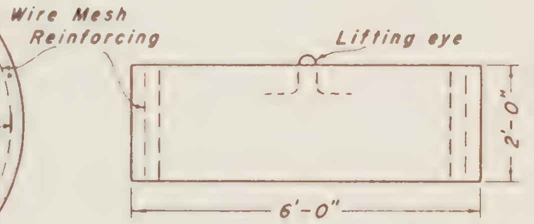


— SKETCH PLAN OF INSTALLATION —



— SECTION A-A —





— ELEVATION —

— PLAN —

DETAIL OF

REINFORCED CONCRETE RINGS

FOR BEACH PROTECTION

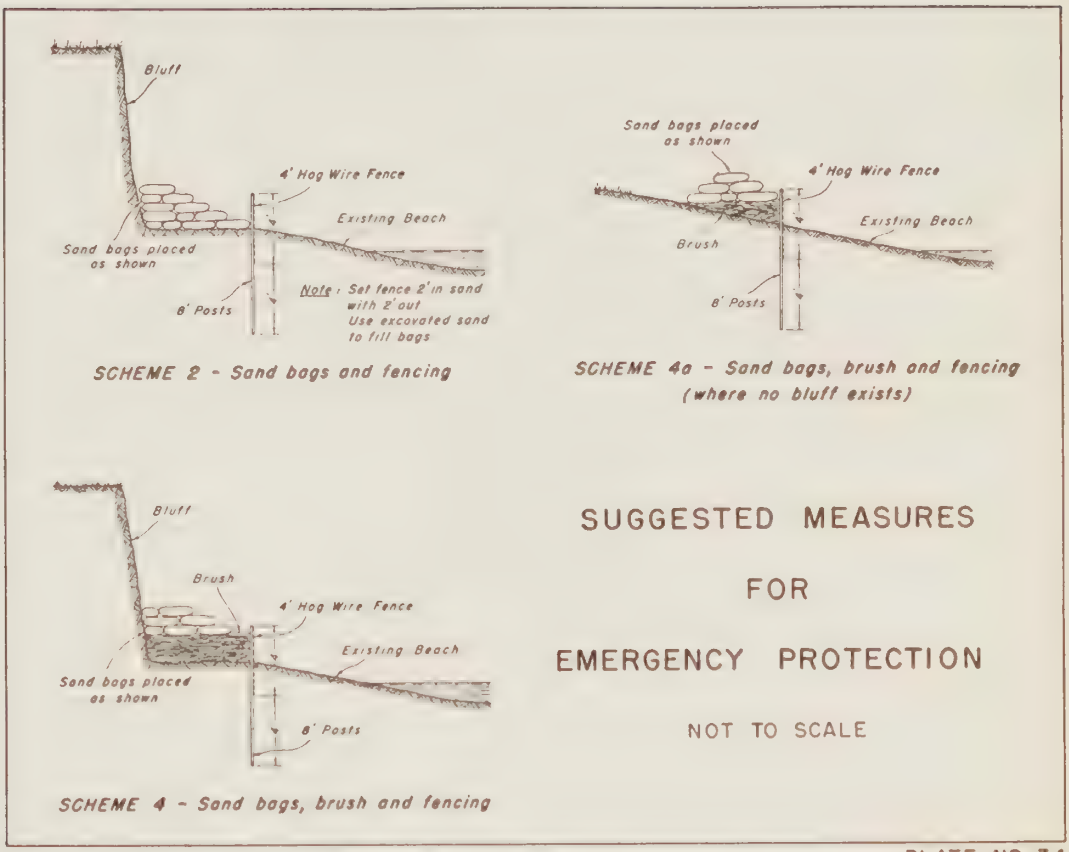


PLATE NO. 34

NOTES

FENCE

Posts should be 4" x 4" x 8' No. 1 timber or equivalent metal section on 5' centres. Wire should be heaviest type hog wire available securely fastened to posts on the landward side. Use 48" wire with 3" x 6" mesh.

PLACING — Set posts 6' in sand or as deep as material permits — set wire 2' in sand with 2' extending above surface.

BRUSH

Brush should be cut and piled in loose in a solid mat with the tops facing lakeward. Place tight against the fence, 2' to 2½' thick by about 7' wide.

SAND BAGS

Sand bags should be filled with sand or gravel if available. If not, fill with any readily available local material. Cement should be mixed with material before filling bags. Use 1 part of cement to 4½ to 9 parts of material, depending on material. 9 parts with clean sand ranging to 4½ parts cement with fine silt or coarse gravel. Care should be used to place sand bags according to the sketches to prevent piping. One-man stone or broken concrete may be substituted for sand bags if available and more economical.

LOCATION

Protection should be placed at the foot of the bluff and tight against the bluff. Where bluff is not present, locate the protection along the line of last resistance but not lakeward of 1' above the present normal limit of uprush.

ADDITIONAL SUPPORT

The sections shown have been tested in the model only. Full-scale construction under actual lake conditions may require additional support for the fence. If required, this can be provided by driving a 4" x 4" x 5' post flush with the sand immediately behind the sand bag protection and securely fastening a 2" x 4" from the top of this post to the fence post 2' below the top.

SUBMISSIONS AND HEARINGS

Cities

Kingston	Toronto
Oshawa	Windsor
Sarnia	

Towns

Burlington	Oakville
Goderich	Port Dalhousie
Grimsby	Port Hope
Kincardine	Riverside
Mimico	Tecumseh
Niagara-on-the-Lake	

Villages

Belle River	St. Clair Beach
Long Branch	

Townships

Anderdon	North Grimsby
Bosanquet	Pelee Island
Clinton	Pickering
Colchester South	Plympton
Dunn	Rainham
Goderich	Saltfleet
Gosfield South	Sandwich East
Grantham	Sandwich West
Grimsby North	Scarborough
Halton	South Cayuga
Hay	Stanley
Howe Island	Stephen
Louth	Trafalgar
Maidstone	Turnbury
Malden	Walpole
Mersea	Wolfe Island
Moulton	Woodhouse
Niagara	

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Burlington Beach Commission

Hydro-Electric Power Commission of Ontario

Individuals

C. G. R. Armstrong

C. M. Bonham

H. Spencer Clark

Jan Demick

S. H. Fleming

J. B. Laidlaw

D. G. Ure

Departments of Government

Provincial

Attorney-General

Health

Highways

Lands and Forests

Mines

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Public Works

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Transport

United States

Corps of Engineers, United States Army

Department of Natural Resources, State of Ohio

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Select Committee on
Report of the Select Committee of the On-
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